Commerce Spectrum Management Advisory Committee (CSMAC)

Working Group 3 (WG 3) Report on

1755-1850 MHz Satellite Control and Electronic Warfare

Contents

1 Introduction

CSMAC WG 3 developed the following mission statement to guide its work:

Mission Statement

> CSMAC WG 3 will focus on recommendations to optimize industry access to the 1755-1850 MHz band while protecting federal operations. This work shall consider the entire 1755-1850 MHz band while taking into account the industry priority to access to 1755-1780 MHz first. Deliverables include recommendations regarding definition and specification for sharing techniques with satellite operations (including any interference acceptance rules and coordination zones) and improved coordination rules and procedures for electronic warfare.

1.1 Executive Summary of Working Group Findings

CSMAC WG 3 was responsible to study the sharing between satellite control systems and Long Term Evolution (LTE) (LTE is a standard for wireless mobile communication standardized by 3GPP) as well as LTE and Electronic Warfare in the 1755-1850 MHz band. Three interference scenarios were identified and the following conclusions were reached.

With respect to potential harmful interference caused by LTE devices to satellite control systems (SATOPS), working group analysis found negligible interference predicted to all satellite programs except possibly a few experimental spacecraft based upon current deployment and operational assumptions. A power flux density of -179 dBW/Hz/m^2 was determined to be a safe interference level for satellites in geostationary orbit. Specifying the protection level for geostationary orbit also protects satellites at other altitudes.

With respect to potential harmful interference by SATOPS ground stations to LTE base stations, analysis showed that the SATOPS ground stations only radiate a relatively small percentage of the time: 8-13% of the time in the lower portions of the band (1761-1780 MHz), with higher radiating percentages in the upper (1780-1842 MHz) portions of the band. Analysis found that when the SATOPS ground stations radiate, they only use a small fraction of the overall band (typically 0.2 to 4 MHz of the 1761-1842 MHz band) at any one time. The group identified a number of technologies and techniques with significant potential to mitigate harmful interference when it does occur. It therefore concluded that LTE operations can effectively share the 1761-1842 MHz band with satellite operations.

With respect to Electronic Warfare, the group recommended continuing Electronic Warfare (EW) Research, Development, Test and Evaluation (RDT&E), training and Large Force Exercise (LFE) operations in the band, on DoD ranges and within associated airspace, on a Non-Interference Basis (NIB) using existing national coordination procedures.

In summary, CSMAC WG 3 concluded that satellite control systems and Electronic Warfare operation can co-exist with LTE operations in the 1755-1850 MHz band.

1.2 Summary of WG 3 Recommendations for Presentation to CSMAC

Below are all the recommendations from CSMAC WG 3. The recommendations number is a reference to the section of the report from which they originate.

Recommendation 3.2.1-1: The CSMAC recommends that NTIA allow the federal agencies to continue to conduct EW RDT&E, training and LFE operations on DoD ranges and within associated airspace on a NIB with commercial wireless operations, if introduced to the band.

Recommendation 3.2.1-2: The CSMAC recommends that NTIA and FCC evaluate current simulation and modeling tools, techniques and management processes used to coordinate EW RDT&E, training and LFE operations to ensure they are robust enough to allow timely and effective deconfliction with potential commercial wireless operations in the band.

Recommendation 3.2.1-3: The CSMAC recommends that NTIA, FCC and DoD assess the usefulness of establishing a formal coordination process between DoD and commercial wireless service providers to assist with spectrum sharing issues on a localized basis.

Recommendation 3.2.1-4: The CSMAC recommends that NTIA add additional information concerning the procedures for performing EA in the United States to section 7.14, Use of Frequencies for the Performance of Electronic Attack Test, Training and Exercise Operations, of the NTIA Manual. (see section 3.2.3)

Recommendation 4.2.3-1: NTIA should direct federal earth station operators to document in their transition plans publicly releasable information to allow prospective licensees to understand the potential impact to any base station receivers from SATOPS uplinks. Detailed information to be provided by the federal users should include:

- Contours within which radiated power levels from federal earth stations is likely to exceed the -137.4 dBW LTE interference threshold (1 dB desense) assuming worst case conditions of maximum transmit power at minimum elevation angle.
- Contours within which radiated power levels from federal earth stations is likely to remain below the -137.4 dBW LTE interference threshold (1 dB desense) as calculated at 100%, 99%, and 95% of the time assuming nominal operating conditions, based on recent historical use. Usage of federal earth stations can and will change with time, and is not limited by the information provided.

Recommendation 4.2.3-2: NTIA should recommend that the FCC, in consultation with the NTIA, consider methods to allow government agencies to share with commercial licensees information relevant to spectrum sharing in the vicinity of federal earth stations, subject to appropriate non-disclosure or other agreements, consistent with US law and government policies.

Recommendation 4.2.3-3: The space operation service (Earth-to-space) remains a primary service in the 1761 – 1842 MHz band, as defined in Government footnote G42.

Recommendation 4.2.3-4: NTIA should recommend the FCC require that commercial licensees accept interference from federal SATOPS earth stations operating in the 1761-1842 MHz band.

Recommendation 4.2.3-5: NTIA should direct federal earth station operators to identify and document in their transition plans the cost and schedule required to accelerate and/or expand the transition of all federal earth stations to radiate a narrower bandwidth signal.

Recommendation 4.2.4-1: NTIA should recommend establishment of rules/regulations with built in flexibility for future SATOPS growth and change, including satellite network and ground station locations/configurations. New federal earth station locations must be determined in coordination with commercial licensees. For existing federal earth stations, federal users must notify commercial licensees of significant changes such as additional antenna or extended anomaly support.

Recommendation 4.2.4-2: NTIA should recommend all federal costs related to planning, sharing and continued compatibility activities for satellite sharing should be part of the federal agencies' cost estimate and fundable through the Spectrum Relocation Fund (SRF). Agencies should remain eligible for SRF funds as long as federal agencies operate and incur costs related to sharing satellite operations with commercial operation in the 1761-1842 MHz band.

Recommendation 4.2.4-3: NTIA should recommend that the FCC, in consultation with NTIA and relevant federal agencies, develop methods for licensees in the 1761-1842 MHz band to demonstrate technologies or techniques that ensure commercial operations can accept interference from the satellite operations when operating within the zones where the nominal SATOPS power is expected to exceed the LTE interference threshold (a 1 dB desense), prior to deployment of base stations in the zones.

Recommendation 4.2.6-1: CSMAC recommends that the FCC propose in their rulemaking a requirement on licensees which overlap any of the 1761-1842 MHz band that specifies a technical showing of compatibility with satellite uplinks.

- The aggregate for all licensees on the same frequency is a compliance level, in terms of power flux density at the geostationary orbit (GSO), not to exceed -179 $dBW/Hz/m^2$.
- The initial showing shall be provided no later than 2 years after the issuance of the license and must contain technical data supporting the current deployment and an projected estimate of the deployment for 5 years in the future.
- The showing shall be updated on a periodic basis to be determined by the FCC.
- Due to the nature of such a showing, all data shall be proprietary between the licensee, FCC and NTIA (including government earth station operators).

Draft Recommendation 4.2.6-2: CSMAC recommends the FCC consider in its rulemaking methods to ensure that the following conditions be met to ensure the aggregate commercial wireless mobile broadband emissions will not exceed the acceptable threshold power level, including:

- Method to aggregate the individual showings into a single value expected at the GSO arc from all licensees.
- The actions to be taken by the FCC to reduce the projected aggregate emissions if it is projected to exceed the threshold.
- The actions to be taken by the FCC to eliminate harmful interference if it does occur, to include potential cessation of operations by the commercial licensee(s) on the affected frequency until interference is resolved.

Recommendation 4.2.6-3: CSMAC recommends the NTIA investigate measures that can be implemented in its NTIA manual to enhance future spectrum sharing with mobile broadband networks. One approach could be to specify power radiated at the horizon from new SATOPS terminals similar to that found in the NTIA manual at Section 8.2.35.

1.3 Next Steps/Path Forward

This report was developed by CSMAC Working Group 3 so that its recommendations could be taken into consideration by NTIA when coordinating with the FCC on any steps related to an auction and reallocation of these bands. The efforts documented here should also inform any resulting development of transition plans related to auction, reallocation and/or sharing of these bands.

Electronic Warfare - Continue EW RDT&E, training and LFE operations in the 1755-1850 MHz band on DoD ranges and within associated airspace on a NIB using the existing national level procedures to coordinate EA operations between federal agencies and the FCC. Additionally, NTIA, FCC and DoD assess that existing simulation and modeling tools and management processes are adequate to provide timely and effective deconfliction between current and future mobile wireless networks and federal EW systems to ensure continued EW RDT&E, training and LFE operations without disruption of commercial wireless services. Finally, implement guidance, processes and mechanisms through the NTIA Manual and FCC Rules to allow for the creation of a formal coordination process between DoD and commercial wireless service providers on a localized basis in the event that interference thresholds could be exceeded or in the event of other unusual circumstances that may arise.

2 Organization and Functioning of the Working Group

2.1 Organization of WG 3

The working group is composed of approximately 90 members from DoD and Industry. The full list of the membership can be found in Section 5 of this report. The chairs, CSMAC member participants, CSMAC liaisons and the FCC/NTIA points of contact for the group are:

CSMAC Working Group 3		
Co-Chairs	Alexander Gerdenitsch	COL Harold Martin
	Robert Kubik	
CSMAC Member Liaison	Rick Reaser	Charlie Rush
CSMAC Member Participants	Thomas Dombrowsky Jr	Janice Obuchowski
NTIA POC	Rob Haines	
FCC	Peter Giorgio	John Kennedy

2.2 Work Plan

The efforts of the group were pursued in four main areas, and were heavily influenced by the availability of publically released or releasable technical and operational details regarding satellite operations. An initial “Phase 1 Analysis of Interference into LTE Base Station Receivers” effort was based on publically available information regarding SATOPS. The government (or federal) facilitated this effort by clearing for public release a “Government Satellite Control Overview” briefing with updates to previously released information such as the “Department of Defense Investigation of the Feasibility of Accommodating the International Mobile Telecommunications (IMT) 2000 Within the 1755-1850 MHz Band” (DoD IMT-2000 Assessment) report.

A “CSMAC WG 3 Phase 2 Study Summary” effort further refined the analysis of potential SATOPS interference with LTE base stations by drawing on additional information regarding SATOPS operational details that were not publically releasable for security reasons. These details allowed the Phase 2 Study to describe not only the contours of SATOPS antenna power for locations around the SATOPS site, but to also model with higher fidelity the probability of an LTE threshold being exceeded by interference from the SATOPS antenna as it varies by location.

A third major effort of study resulted in an “Analysis of Potential Aggregate Long-term Evolution (LTE) Radio Frequency Interference (RFI) to Space-Borne Satellite Operations in 1755-1850 MHz Final Brief” that analyzed the potential impact to satellite operations from LTE sharing of the band. Due to the sensitivity of satellite operations design and operations details, the study was based on information not publically releasable, but resulted in overall conclusions that were cleared for public release documented in this report.

A fourth major effort of the study analyzed and assessed issues related to sharing of the band by LTE with Electronic Warfare activities

2.3 Functioning of WG 3

Working group 3 first met on July 17, 2012 and continued to meet on a recurring 2 week basis. During this time we held three face-to-face meetings and 23 meetings via teleconference. Starting November 28 we initiated a technical sub-working group to discuss modeling methodologies on SATOPS uplink stations into base station receivers. This sub-working group met 8 times. CSMAC WG 3 would like to thank the Telecommunications Industry Association for providing teleconference facilities, and Wiley Rein for providing meeting facilities.

3 Working Group Report

The sections below summarize efforts and recommendations related to sharing of the 1755-1850 MHz Band by LTE with both Satellite Control and Electronic Warfare Operations. The Satellite Control section analyzes both interference to satellite control systems (receivers on board orbiting spacecraft) and interference to mobile broadband (LTE) systems. The analysis of interference to LTE systems includes both the initial efforts based on publically releasable information, and subsequent efforts that accounted for additional information not publically releasable.

3.1 Satellite Control

Two paths of interference were evaluated by the Working Group, the first path is interference to Satellite space-borne receivers from an aggregate of transmitting LTE mobile devices. The second is interference from transmitting satellite earth terminal to an LTE receiving base station.

3.1.1 Interference to Satellite Control Systems

The working group examined aggregate LTE interference to satellite operations (SATOPS) on-board orbiting spacecraft in the 1755-1850 MHz band. The analysis can be found in Section 4.2.6 of this report, analysis was based on CSMAC Working Group 1 (WG 1) assumptions about LTE parameters (November 2012 revision). CSMAC WG 3 concluded that there is low risk of harmful interference from aggregate LTE to SATOPS based on current assumptions.

Most major Air Force and Navy programs were analyzed. An interference level of -205 dBW/Hz into a SATOPS receiver, assuming a 0 dBi antenna and no other losses, (equivalent to a power flux density of -179 dBW/Hz/m^2) was determined to be a safe interference level at geostationary orbit for most programs. This level was derived from requirements documented for all programs. It also ensures a safe level of RFI for most low earth orbit programs. Satellite receiver designs/technology are not expected to change significantly in the future.

Analysis indicated that aggregate mean interference was estimated to be -212.6 dBW/Hz (7.6 dB below the safe level). However, a few experimental programs may not be protected by this level. Therefore additional consideration is needed for the experimental programs, e.g., during transition planning. Analysis also found insignificant interference variation due to LTE power control (σ = 0.12 dB).

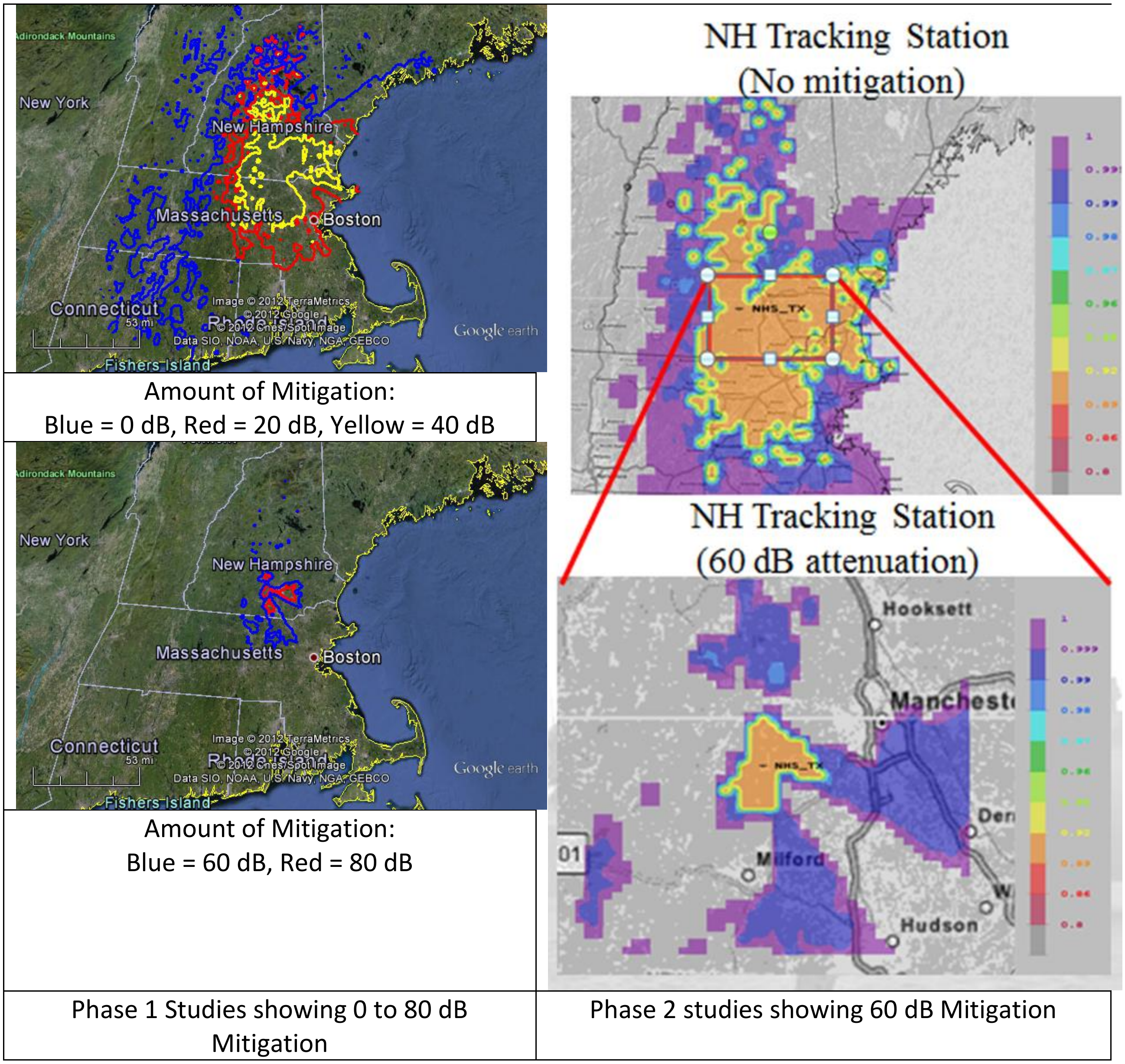
In conclusion, analysis found negligible interference predicted to all programs except possibly a few experimental spacecraft

3.1.2 Interference to Mobile Broadband Systems

The team developed results to describe SATOPS transmitting earth terminal interference into LTE base station receive operations. The analysis can be found in Sections 4.2.3 and 4.2.4 of this report. The study developed contours outside which interference is below a specified level into LTE operations is predicted. Due to the time varying nature of SATOPS earth terminal operation there would be increasing probability of interference (temporal) to LTE with proximity to SATOPS ground station. Potential mitigation techniques were identified for further evaluation and implementation by licensees that may reduce interference impacts from SATOPS to LTE.

This work was performed in two phases, the initial "Phase 1 Analysis of Interference into LTE Base Station Receivers" effort was based on publically available information regarding SATOPS and is found in Section 4.2.3. A "CSMAC WG 3 Phase 2 Study Summary" effort further refined the analysis of potential SATOPS interference with LTE base stations by drawing on additional information regarding SATOPS operational details that were not publically releasable for security reasons, this effort is described in Section 4.2.4.

Figure 3.1.2-1 shows example results of both phases of study when interference mitigation techniques are applied. Both phase of studies show a very significant reduction in the distance at which an LTE base station receiver would be interfered with. The Phase 1 studies provide the zones in which a base station would receive interference in excess of a 1 dB desense threshold. The Phase 2 studies shows a similar result with the added detail about how often that level may be exceeded. The two figures are not exactly the same as the Phase 2 studies was performed with a different set of parameters that are not part of the public domain. Even with this difference, the two phases of study are in general agreement.



Amount of Mitigation:
Blue = 0 dB, Red = 20 dB, Yellow = 40 dB

Amount of Mitigation:
Blue = 60 dB, Red = 80 dB

Phase 1 Studies showing 0 to 80 dB Mitigation

Phase 2 studies showing 60 dB Mitigation

Figure 3.1.2-1: Reduction of interference zones based on various levels of mitigation.

The team concluded that SATOPS uplinks will not interfere with LTE base stations outside the contours identified.

3.2 Electronic Warfare (EW)

The Department of Defense's (DoD) ability to conduct research, development, test and evaluation (RDT&E) of electronic warfare (EW) systems and provide realistic EW training, to include large force employment exercises (LFEs), with fielded EW systems to U.S. forces, are essential to countering existing and emerging threat systems within the 1755-1850 MHz band.

Relocation of EW systems from the 1755-1850 MHz band would leave U.S. forces unprotected and vulnerable from threats operating in this band and is therefore not a viable option. Currently, the 1755-1850 MHz band is designated for exclusive federal use only, where EW operations are conducted on a non-interfere basis (NIB) with other federal agencies operating in the band using national level coordination procedures. Electronic attack (EA) RDT&E, training and LFE coordination is limited to the effected federal agencies. Sharing the 1755-1850 MHz band with commercial wireless carriers will complicate this process enormously. Enhancements to existing procedures must take place to enable commercial wireless broadband service while maintaining EW RDT&E, training and LFE capabilities in and around approved federal test and training ranges and operating areas.

3.2.1 Summary of Electronic Warfare Recommendations

Recommendation 3.2.1-1: The CSMAC recommends that NTIA allow the federal agencies to continue to conduct EW RDT&E, training and LFE operations on DoD ranges and within associated airspace on a NIB with commercial wireless operations, if introduced to the band.

Recommendation 3.2.1-2: The CSMAC recommends that NTIA and FCC evaluate current simulation and modeling tools, techniques and management processes used to coordinate EW RDT&E, training and LFE operations to ensure they are robust enough to allow timely and effective deconfliction with potential commercial wireless operations in the band.

Recommendation 3.2.1-3: The CSMAC recommends that NTIA, FCC and DoD assess the usefulness of establishing a formal coordination process between DoD and commercial wireless service providers to assist with spectrum sharing issues on a localized basis.

Recommendation 3.2.1-4: The CSMAC recommends that NTIA add additional information concerning the procedures for performing EA in the United States to section 7.14, Use of Frequencies for the Performance of Electronic Attack Test, Training and Exercise Operations, of the NTIA Manual.

3.2.2 Report

EW consists of military actions involving the use of electromagnetic (EM) energy and directed energy (DE) to control the electromagnetic spectrum (EMS). Successful military operations require unfettered access to, and use of, the EMS. All modern forces rely on spectrum dependent systems (SDS) for communications; command and control (C2); intelligence, reconnaissance and surveillance (ISR); position, navigation and timing (PNT); radar; and precision weapons employment. EW is essential for the protection of these operations for friendly forces, while denying their use to an adversary. The value of EW has been clearly demonstrated in current operations in Iraq and Afghanistan, where U.S. forces have successfully countered radio controlled improvised explosive devices (RCIEDs), saving countless lives and protecting vital operations.

To ensure continued successful military operations, robust RDT&E, training and LFE operations, driven by existing and emerging threat systems, must be maintained. In the 1755-1850 MHz band, the threat is propelled by the explosion of commercial wireless systems being employed in nontraditional ways against U.S. forces. To ensure the continued protection of U.S. operations, forces must be equipped with cutting edge EW equipment and thoroughly trained in the most current employment tactics, techniques and procedures (TTPs). Additionally, effective EW RDT&E, training and LFE operations must be conducted against realistic threat systems and simulations. Therefore it is a requirement to maintain the ability to field and operate realistic training threat systems on DoD test and training ranges.

Currently, EA, a division of EW involving the use of EM, DE or anti-radiation weapons to attack an adversary with the intent to degrade, neutralize or destroy its combat capabilities, is not recognized by the NTIA, or FCC as an authorized service outside DoD test and training ranges. However, with proper coordination, as defined by national and DoD regulations, EA may be performed under the condition that harmful interference will not affect authorized services. Coordination is conducted at the national level and based on the desired EA frequency band, geographical area, time and duration of EA operations. EA clearances are requested and processed through the applicable Military Department (MILDEPS) Spectrum Management Offices (SMOs), who then coordinate the request with applicable federal agencies and the FCC. Though this process is effective, it is a cumbersome and time consuming process that offers very little flexibility.

If the 1755-1850 MHz band is reallocated for commercial use, it is still possible to continue EW RDT&E, training and LFEs operations in the band, but additional enhancements to existing EA coordination procedures and threat system assignment processes will be required. Enhancements to coordination include increasing the time EA clearances are authorized; reduce the EA clearance processing times; acquire improved EA modeling and management tools; and implement procedures to allow EA coordination to take place at the local levels. These enhancements will increase the flexibility and responsiveness of the EA clearance process; add stability to EW RDT&E, training and LFE operations; and enable more effective coordination between commercial industry and federal agencies.

3.2.3 Draft Text for NTIA Manual of Regulations and Procedures

The below is recommended draft text for Federal Radio Frequency Management/Rules and proposed Coordination Procedures for DoD Area Frequency Coordinator, or Fleet Area Control and Surveillance Facility, Range Managers and Commercial Wireless Service Providers for the 1755-1850 MHz Band.

> EW operations within the US&P should continue to be conducted in accordance with the NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management, IRAC Document 34279/1, Joint Chiefs of Staff Manual CJCSM 3212.02B, dated October 15, 2003, titled Performing Electronic Attack in the United States and Canada for Tests, Training and Exercises. This manual contains details concerning Agency and organizational responsibilities regarding radio frequency (RF) clearance coordination for the performance of EA in the United States. Due to restrictions that limit the release of CJCSM 3212.02B to DoD components and other federal agencies only, combined with the increased coordination requirements that will be generated between the federal

agencies and the commercial wireless service providers, the following paragraphs should be added to section 7.14, Use of Frequencies for the Performance of Electronic Attack Test, Training and Exercise Operations, of the NTIA Manual.

The Administrator, NTIA, discharges radio communication and frequency management functions for the federal government with the advice of the Interdepartmental Radio Advisory Committee (IRAC). The IRAC consists of representatives from key government departments and agencies, including each Military Department. The United States Table of Frequency Allocations, published in the Federal Register, is the source document listing authorized federal government and nonfederal government RF spectrum allocations for the United States. This table defines frequency allocations as primary and secondary services. Authorized users have the right to operate in their respective services free from harmful interference. Outside of DOD EW test and training ranges, EA is not recognized by the NTIA or the FCC as an authorized service. With the proper coordination, however, EA may be performed under the condition that harmful interference will not affect authorized services.

EA coordination minimizes the likelihood of EA harmful interference to authorized RF spectrum users. In an increasingly crowded and dynamic RF spectrum, proper EA coordination serves to protect the portions of the spectrum currently available for EA from restrictions caused by occurrences of unintentional harmful interference. EA coordination is required when a user desires to conduct EA in a frequency band where authorized users of primary or secondary services are assigned. National-level coordination involves submitting an EA clearance request through the applicable federal agency SMOs in order to obtain an EA clearance. The coordination requirements for EA in the United States are based on the desired EA frequency band, the geographical area, proposed duration and time of the EA operation.

NTIA and FCC will support the establishment of local EA coordination working groups that will be convened as required to provide subject matter expertise and support to develop recommendations for resolving local EA clearance restrictions; facilitate expedited EA clearance coordination for short-notice, high priority EA test and training events; and identify possible sharing technologies, procedures and process that could be implemented to allow EA test and training without disrupting authorized use of the band. Local EA coordination working groups should be tailored to meet the necessary tasks, and as required, consist of representatives from the NTIA, FCC, DoD area frequency coordinator (AFC) or fleet area coordination and surveillance facility (FACSFAC), DoD range managers and frequency managers, DoD event coordinators, the Range Commander Council Frequency Management Group (RCC-FMG), applicable federal agencies and commercial wireless carriers. These local working groups will be tasked by, and report to the federal regulators (FCC and NTIA) and federal agency coordination authority (e.g. MILDEP SMOs, FAA National HQ, and NASA). Each local EA coordination working group will be chaired by the corresponding AFC/FACSFAC representative. All recommendations from a local EA coordination working group must be approved by National Level Coordination Authorities and/or Federal Regulators before being implemented. In order to share information and best practices, all local EA coordination working group members will meet as a whole once a year in conjunction with RCC-FMG meetings.

4 Technical Appendices

4.1 Overview of Technical Appendices

The technical appendices are organized to reflect the CSMAC WG 3 assigned study items. Section 4.2 address the studies for sharing between satellite control systems and LTE, subsections provide details about parameters for LTE and Satellite operations, evaluation of satellite orbital statistics, phase 1 and 2 interference analysis from SATOPS earth terminals to LTE base station receivers, mitigation concepts to reduce interference to LTE base station receivers and analysis of interference from LTE mobile transmitters to space-borne satellite receivers. Section 4.3 addresses evaluation of LTE and Electronic Warfare in the 1755-1850 MHz band. Section 4.4 provides government cleared submissions to CSMAC WG 3 process.

4.2 Satellite Control Technical Appendices

4.2.1 Parameters of LTE and Satellite Operations

4.2.1.1 Satellite Operations

The locations for evaluation of sharing between SATOPS earth terminal and mobile broadband systems should be based on the Table 4.2.1-1 through 4.2.1-3. These tables are based on information provided in the NTIA Special publication 01-46 and on data provided by DOD.[1]

[1] NTIA Special Publication 01-46, "The Potential for Accommodating Third Generation Mobile Systems in The 1710-1850 MHz Band: Federal Operations, Relocation Costs, and Operational Impacts".

Table 4.2.1-1: Government Tracking Sites

Site	Abbreviation	Facility
Annapolis, Maryland	AN, MD	Other
Buckley AFB, Colorado	BAFB	Other
Blossom Point, Maryland	BP, MD	Navy
Cape GA, CCAFB, Florida	CAPEG	Other
Camp Parks, California	CP, CA	Other
Colorado Tracking Station, Schriever AFB, Colorado	CTS	AFSCN
Diego Garcia Tracking Station, British Indian Ocean Territory, Diego Garcia	DGS	AFSCN
Eastern Vehicle Checkout Facility, Cape Canaveral AFS, Florida (Launch support only)	EVCF	AFSCN
Fairbanks (NOAA), Alaska	FB, AK	Other
Ft Bragg, NC	FB, NC	Other
Fort Belvoir, Virginia	FB, VA	Other
Ft Hood, TX	FH, TX	Other
NAVSOC Det. Charlie (Navy)	GNS	Navy
Guam Tracking Station, Andersen AFB, Guam	GTS	AFSCN
Huntington Beach , CA	HB, CA	Other
Hawaii Tracking Station, Kaena Point, Oahu, Hawaii	HTS	AFSCN
Joint Base Lewis-McChord, WA	JB, WA	Other
Kirtland AFB, New Mexico	KAFB	Other
JIATF-S, Key West, FL	KW, FL	Other
Laguna Peak, California (Navy)	LP, CA	Navy
Monterey, California	MO, CA	Other
New Hampshire Tracking Station, New Boston AFS, New Hampshire	NHS	AFSCN
Prospect Harbor, Maine (Navy)	PH, ME	Navy
Patuxent River NAS, MD	PR, MD	Other
Sacramento, CA	SAC, CA	Other
Oakhanger Telemetry and Command Station, Borden, Hampshire, England	TCS	AFSCN
Thule Tracking Station, Thule Air Base, Greenland	TTS	AFSCN
Vandenberg Tracking Station, Vandenberg AFB, California	VTS	AFSCN

Table 4.2.1-2: Locations and Transmit Information for SATOPS Sites

SATOP Site	Latitude	Longitude	Elevation above MSL (m)	Max Transmit Power (dBW)[2]	Max Antenna Gain (dB)	Auth Spectrum Use (MHz)
AN,MD	38-59-26.93N	76-29-24.74W	24	14.8	36	81
BAFB	39-42-55N	104-46-29W	1726	32	43	81
BP, MD	38-25-53.5N	77-05-06.4W	19	25	46	81
CAPEG	28-29-03N	80-34-21W	6	24	40	81
CP, CA	37-43-51N	121-52-50W	300	30	42	81
CTS	38-48-21.6N	104-31-40.8W	1910	31.2	45	81
EVCF	28-29-09N	080-34-33W	2	23	28	81
FB, AK	64-58-26N	212-29-39E	385	25	43	81
FB, NC	35-09-04N	78-59-13W	89	24	26.8	81
FB, VA	38-44-04N	077-09-12.5W	61	25	40	81
FH, TX	31-08-57N	97-46-12W	300	24	26.8	81
GNS	13-34-57.6	144-50-31.6E	208	15	40	81
GTS	13-36-54N	144-51-21.6E	218	37.1	45.1	81
HB,CA	33-44-49.89N	118-2-3.84W	11	24	26.8	81
HTS	21-33-43.2N	158-14-31.2W	430	32.1	45.4	81
JB,WA	47-06-11N	122-33-11W	86	24	26.8	81
KAFB	34-59-46N	106-30-28W	1600	28	38.4	81
KW, FL	24-32-36N	81-48-17W	2	24	26.8	81
LP, CA	34-06-31N	119-03-53W	439	31	43	81
MO,CA	36-35-42N	121-52-28W	102	14.8	36	81
NHS	42-56-45.6N	71-37-44.4W	200	38.6	45	81
PH, ME	44-24-16N	068-00-46W	6	31	38	81
PR, MD	38-16-28N	76-24-45W	6	24	26.8	81
SAC,CA	38-39-59N	121-23-33W	23	24	26.8	81
VTS	34-49-22.8N	120-30-7.2W	269	37.1	45	81

[2] The maximum radiated power show in this table is the maximum transmit power supplied to the antenna.

Table 4.2.1-3: Locations and Operational Information for SATOPS Sites

SATOP Site	**Radiation Time (%)**	**Instantaneous Spectrum Use Max (MHz)**	**Percent of Spacecraft in 1755-1780 MHz Sub-Band**	**% GEO Support**
AN, MD	4	2	100	0
BAFB	18	2	0	100
BP, MD	45	5	100	0
CAPEG	46	2	0	0
CP, CA	Not currently operational	-	-	-
CTS	30	4	17	40
EVCF	< 1	4	17	40
FB, AK	11	2	0	0
FB, NC	2	1	0	0
FB, VA	20	4	0	50
FH, TX	2	1	0	0
GNS	9	2	0	100
GTS	100	20	17	40
HB,CA	2	1	0	0
HTS	70	5	17	40
JB,WA	2	1	0	0
KAFB	0.6	2	67	0
KW, FL	2	1	0	0
LP, CA	9	3	0	100
MO,CA	4	2	100	0
NHS	60	6	17	40
PH, ME	3	3	0	100
PR, MD	2	1	0	0
SAC,CA	2	1	0	0
VTS	65	6	17	40

Table Notes:

Percent Radiation Time – Percent of time site is transmitting estimated over a one year period.

Instantaneous Spectrum Use - The maximum spectrum amount in use at site at any single point in time.

Percent Spacecraft in Sub-Band - The percentage of spacecraft using the indicated sub-band estimated over a 1 year period.

Percent GEO Support - The percentage of spacecraft using the site that have a GSO orbit.

Shown in Figure 4.2.1-1 is the computed 13 meter reflector antenna pattern, the redline on the figure indicates the NTIA antenna pattern for a peak gain of 47.38 dBi at a frequency of 1795 MHz based on NTIA models for electromagnetic compatibility[3]. For this analysis the antenna pattern for the SATOPS uplinks will be assumed to follow the recommended model as shown in Figure 4.2.1-1 and Figure 4.2.1-2.

---

[3] See NTIA Publication TM-13-489, "Antenna Models for Electromagnetic Compatibility Analysis," at section 6.3.1.3 for an NGSO system earth station antenna co-polarized radiation performance standard. NTIA recommends the side lobe radiation performance standard from the FCC and the main beam pattern from ITU-R S.1428-1.

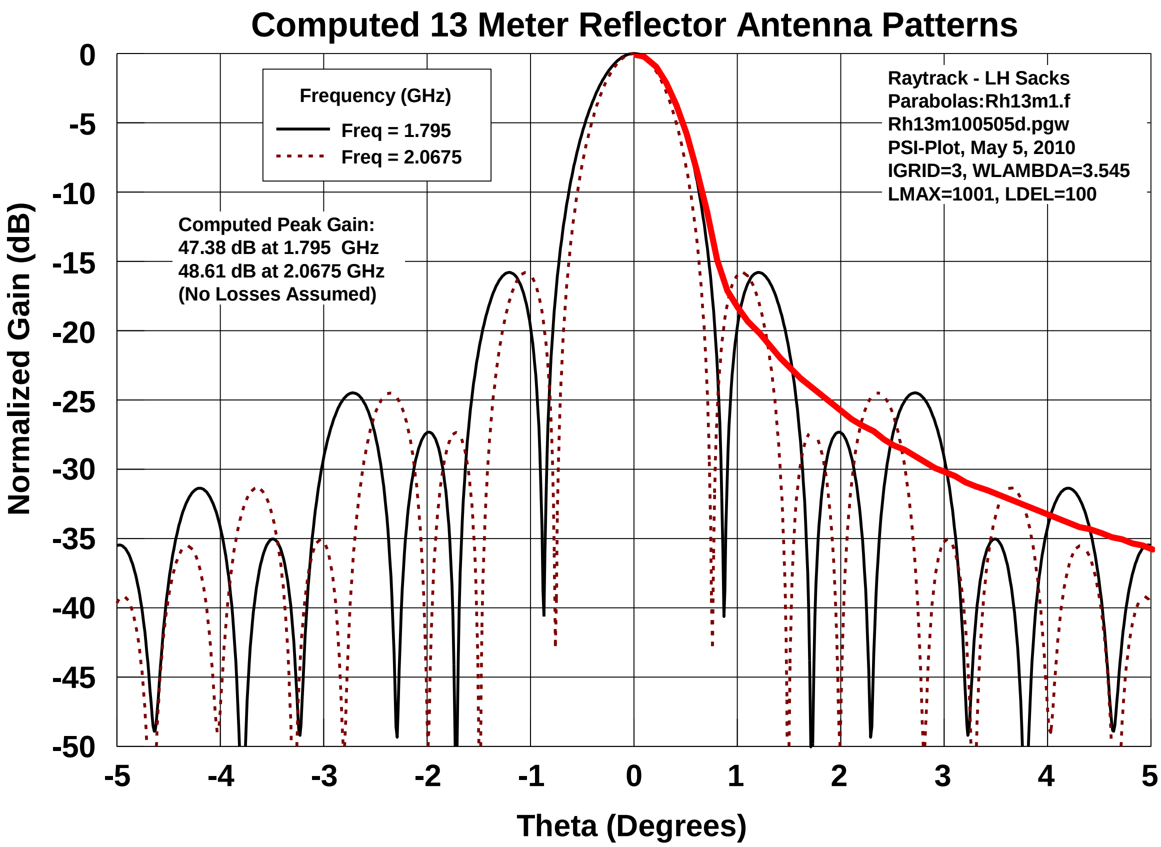


Figure 4.2.1-1: Typical AFSCN Antenna Pattern

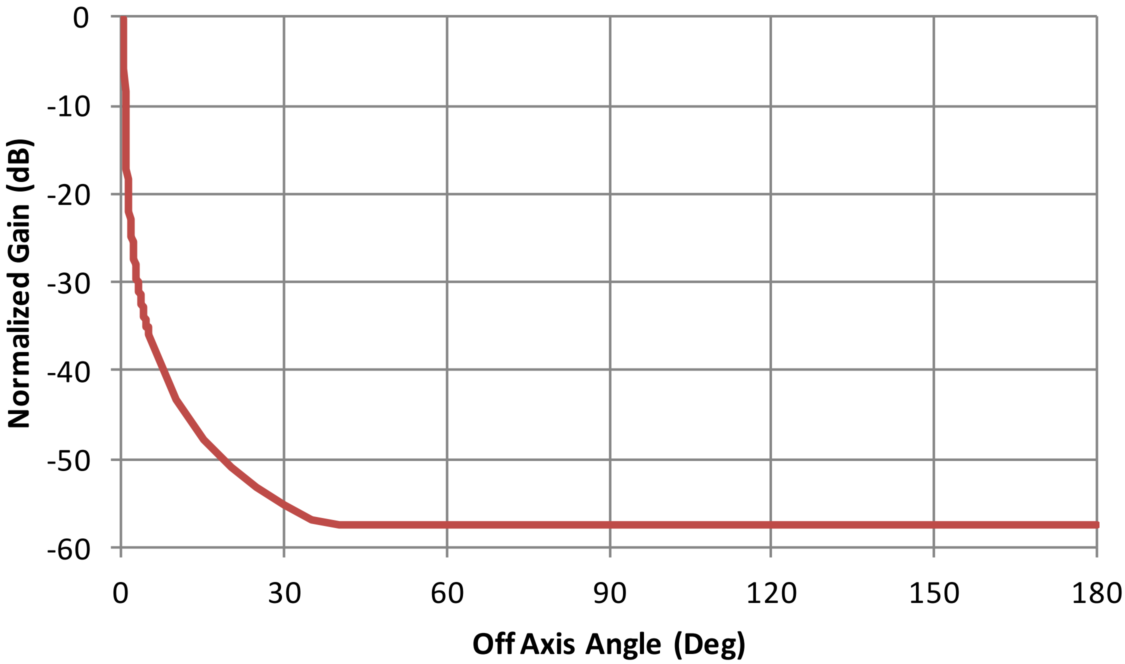


Figure 4.2.1-2: NTIA Recommended Antenna Pattern.

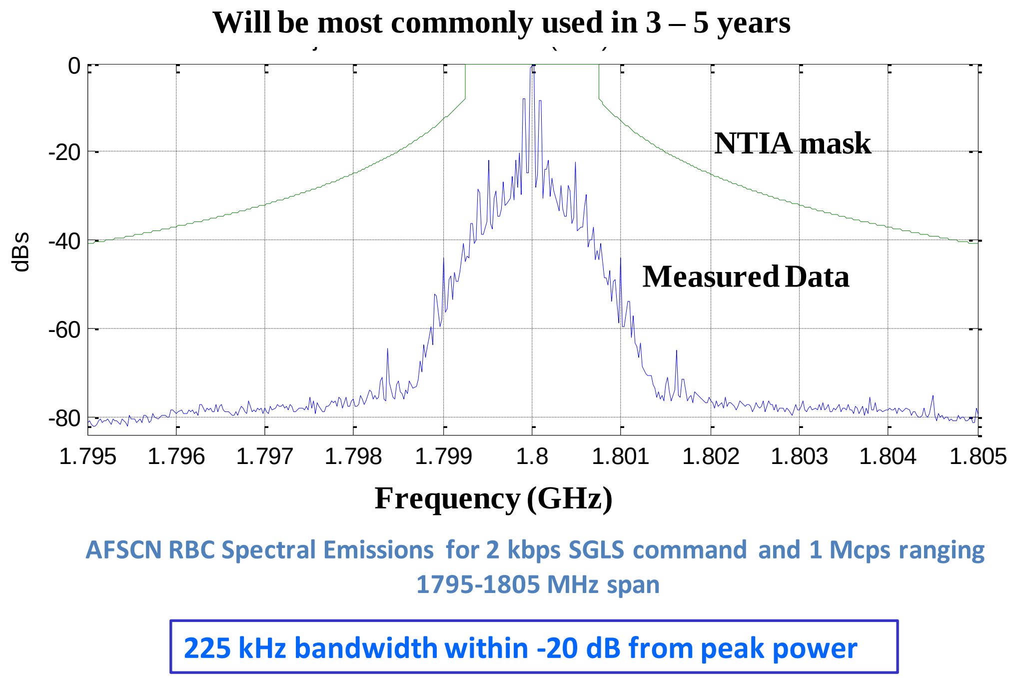


Figure 4.2.1-3: Typical AFSCN Uplink Emission for future operations.

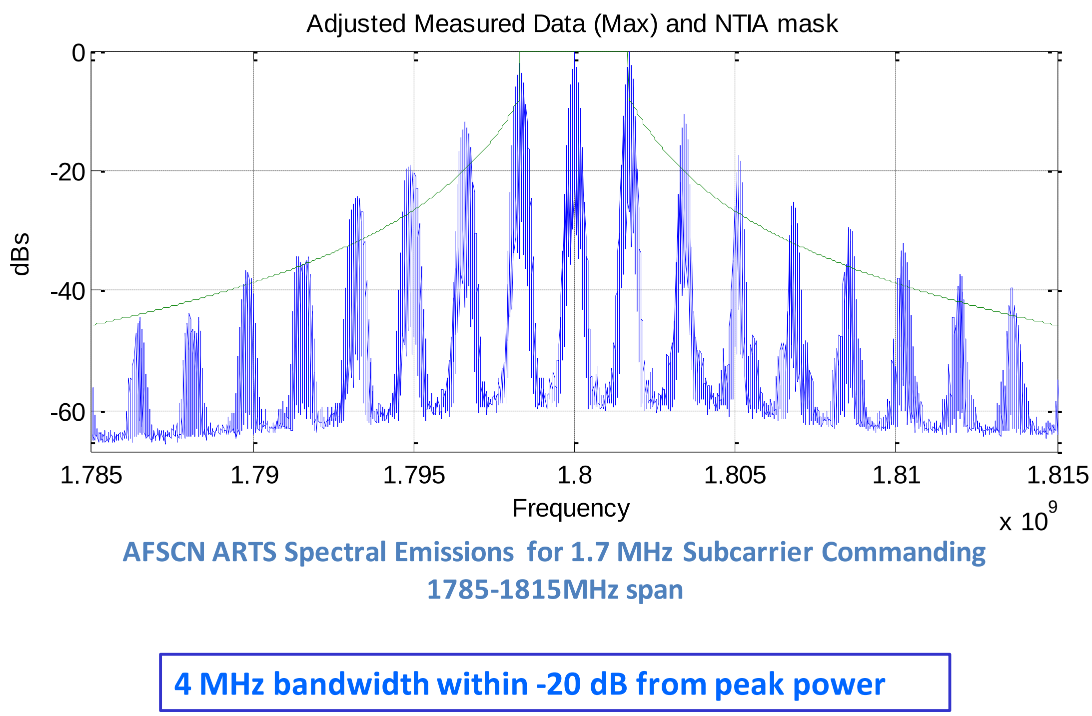


Figure 4.2.1-4: Typical AFSCN Uplink Emission for legacy operations.

4.2.1.1.1 Satellite Coordination Data from ITU Space Networks Database

The International Telecommunications Union (ITU) Space Services Department is responsible for coordination and recording procedures for space systems and earth stations. The Department handles capture, processing and publication of data and carries out examination of frequency assignment notices submitted by administrations for inclusion in the formal coordination procedures or recording in the Master International Frequency Register. This department provides data in the form of a Space Networks Systems Database which contains coordination data of more than 10600 geostationary (GSO) satellite filings, 1070 non-geostationary (NGSO) satellite filings and 7900 earth station filings.[4]

This section summarizes satellite data associated with the US Administration for satellites operating in 1761-1842 MHz for each of the 20 channels associated with the SGLS telemetry system.[5] This data is to be seen as representative of the characteristics of operating satellite systems on a channel-by-channel basis. However, it is noted that in addition there may be several classified satellite systems which are not included in this section.

Figure 4.2.1-5 indicates how many NGSO systems have the ability to operate in each of the 20 SGLS channels. Figure 4.2.1-6 indicates how many GSO systems have the ability to operate in each of the 20 SGLS channels.

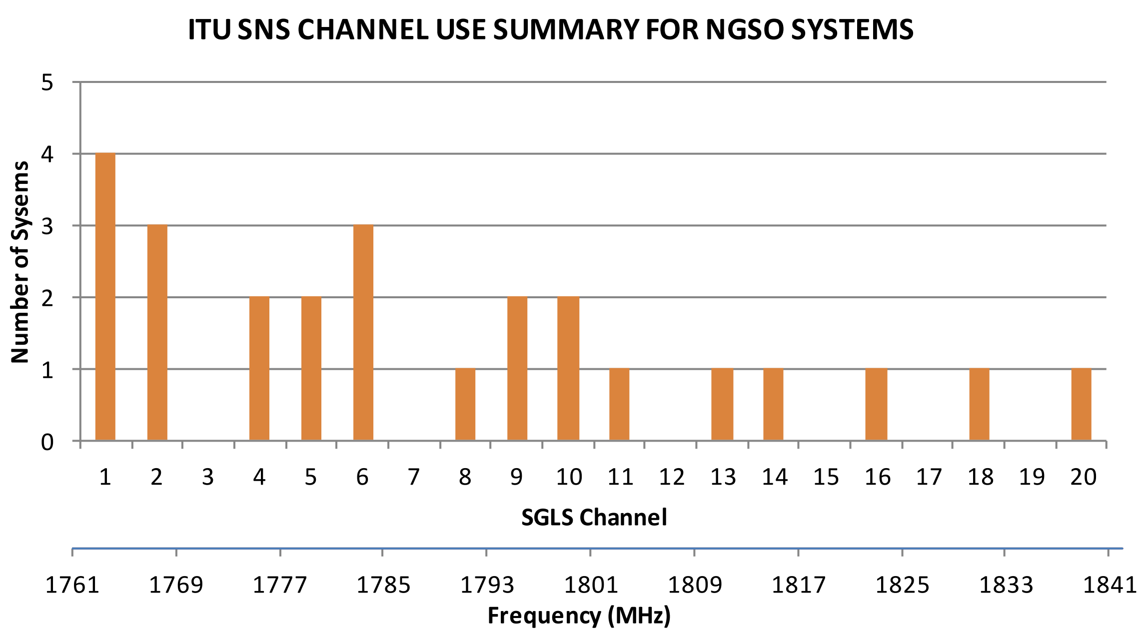


Figure 4.2.1-5: ITU SNS Channel use summary for NGSO Systems.

---

[4] See http://www.itu.int/sns/, visited 11 September 2012.

[5] Data as of 10 August 2012.

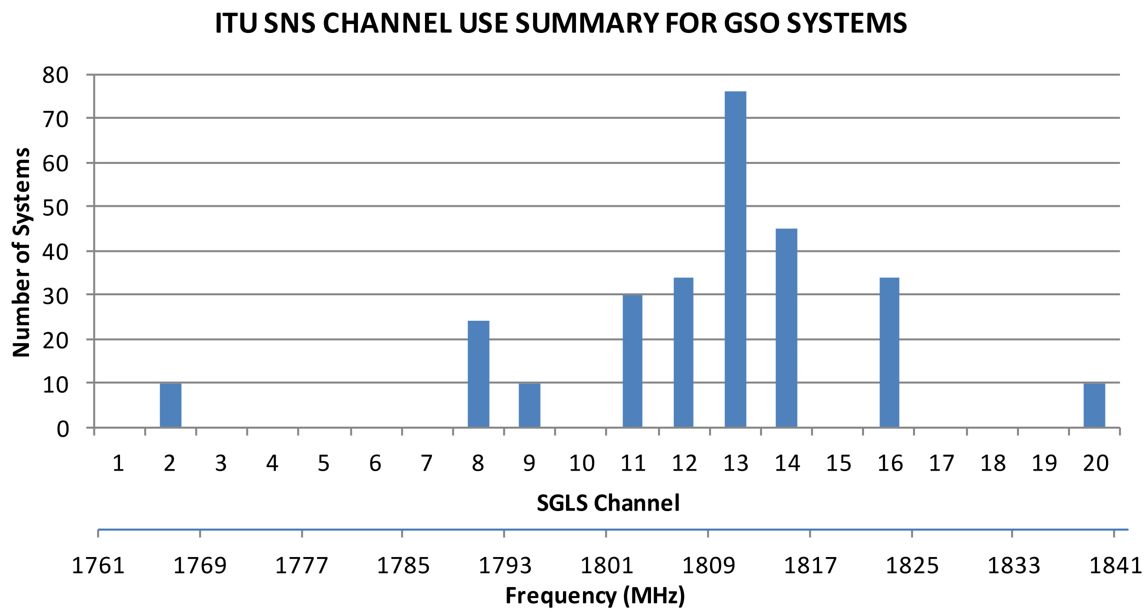


Figure 4.2.1-6: ITU SNS Channel use summary for GSO Systems.

Noting both the 1755-1850 MHz report findings and the industry priority to get access to the 1755-1780 MHz band, approaches should be considered that make that lower band available first, while also dealing with the rest of band up to 1850 MHz to meet agency concerns. To help foster this approach Table 4.2.1-4 and Table 4.2.1-5 provides detailed information on satellite characteristics for the 1755-1780 MHz band (SGLS channels in 1761-1780 MHz) while Table 4.2.1-6 and Table 4.2.1-7 provides similar data for the 1780-1850 MHz band (SGLS channels in 1780-1842 MHz). It should be noted that in the tables for NGSO systems, the convention used is if there is a single orbital plane that the satellite orbits, there will be only one number listed which indicates the number of satellites in that orbital plane. If the satellite constellate is made up of multiple satellites in multiple orbit planes, the convention used is "*a* x *b*" where *a* is the number of orbital planes and *b* is the number of satellites in each orbital plane.

Table 4.2.1-4: NGSO System data for 1761-1780 MHz.

ITU Designation	SGLS Channel(s)	Number of Satellites	Inclination (deg)	Apogee (km)	Perigee (km)	C/N (dB)	Noise Temp (K)	Max Gain (dBi)	Emission Designation
USKW	1	1	98	630	630	15	288	6	4M00G9D
USPOJOAQUE	1	1	40	600	600	15	290	2	2M00G1D
USYV	1	1	99	900	900	15	630	3	4M00G9D
L-92	1, 5, 14, 16	12	55	1300	650	15	5000	0	4M00G7W
MIDSTAR-1	2	1	46	492	492	15	350	2	93K0G1D
P-197-1	2	9	62	39000	470	15	1045	11.5	4M00G7W
USNFR	2	1	49.4	495	495	15	627	4	4M00G9D
ALEXIS	4	1	90	835	740	N/A	438	2	10K0G1D
SPACE SHUTTLE	4, 18	1	57	300	300	N/A	5360	1.5	4M00G2D
CRRES	5	1	28.5	35800	350	N/A	500	5.5	4M00G7W
Adjacent channel									
NAVSTAR GPS	6	3 x 6	55	20200	20200	N/A	1500	4	4M00FXX
USRSR	6	6 x 6	55	20200	20200	10.7	627	13.2	4M00G2D
USKL	6	5 x 2	65	40000	465	15	2250	11	4M00G9D

Table 4.2.1-5: GSO System data for 1761-1780 MHz.

ITU Designation	SGLS Channel(s)	GSO Location (deg)	C/N (dB)	Noise Temp (K)	Max Gain (dBi)	Emission Designation
P-197-2	2	-144	15	1045	11.5	4M00G7W
P-197-3	2	-141	15	1045	11.5	4M00G7W
P-197-4	2	-13	15	1045	11.5	4M00G7W
P-197-5	2	-10	15	1045	11.5	4M00G7W
P-197-6	2	-30.4	15	1045	11.5	4M00G7W
P-197-7	2	92	15	1045	11.5	4M00G7W
P-197-8	2	110	15	1045	11.5	4M00G7W
USNN-3	2, 9, 20	-127	15	5000	-3, 11	4M00G7W
USNN-4	2, 9, 20	100	15	5000	-3, 11	4M00G7W
USNN-5	2, 9, 20	170	15	5000	-3, 11	4M00G7W

Table 4.2.1-6: NGSO System data for 1780-1842 MHz.

ITU Designation	SGLS Channel(s)	Number of Satellites	Inclination (deg)	Apogee (km)	Perigee (km)	C/N (dB)	Noise Temp (K)	Max Gain (dBi)	Emission Designation
L-92	1, 5, 14, 16	12	55	1300	650	15	5000	0	4M00G7W
SPACE SHUTTLE	4, 18	1	57	300	300	N/A	5360	1.5	4M00G2D
NAVSTAR GPS	6	3 x 6	55	20200	20200	N/A	1500	4	4M00FXX
USRSR	6	6 x 6	55	20200	20200	10.7	627	13.2	4M00G2D
USKL	6	5 x 2	65	40000	465	15	2250	11	4M00G9D
BLOCK 5D-3	8	5	81.3	833	833	N/A	870	4	4M00G7W
P92-1	9	5	70	1200	300	N/A	5000	0	4M00G7W
P92-2	9, 20	10	65	40000	465	15	2500, 5000	0, 11	4M00G7W
ORBITAL TEST FLIGHT	10, 13	2	70	550	350	N/A	600	4	4M00G7W
USCP	10	2	58	1350	1350	15	1200	1.5	4M00G9D
USSTP-1	11	1	35.2	560	560	15	627	5	4M00G9D

482 Table 4.2.1-7: GSO System data for 1780-1842 MHz.

ITU Designation	SGLS Channel(s)	GSO Location (deg)	C/N (dB)	Noise Temp (K)	Max Gain (dBi)	Emission Designation
USNN-3	2, 9, 20	-127	15	5000	-3, 11	4M00G7W
USNN-4	2, 9, 20	100	15	5000	-3, 11	4M00G7W
USNN-5	2, 9, 20	170	15	5000	-3, 11	4M00G7W
USOBO-1A	8	-159.4	15	1463	2	4M00G9D
USOBO-1R	8	-159.4	15	1463	2	4M00G9D
USOBO-2	8	-96.8	15	1463	2	4M00G9D
USOBO-2A	8	-96.8	15	1463	2	4M00G9D
USOBO-2R	8	-96.8	15	1463	2	4M00G9D
USOBO-3	8	-49.4	15	1463	2	4M00G9D
USOBO-3A	8	-49.4	15	1463	2	4M00G9D
USOBO-3R	8	-49.4	15	1463	2	4M00G9D
USOBO-4A	8	-21.2	15	1463	2	4M00G9D
USOBO-4R	8	-21.2	15	1463	2	4M00G9D
USOBO-5A	8	20.6	15	1463	2	4M00G9D
USOBO-5R	8	20.6	15	1463	2	4M00G9D
USOBO-6A	8	66	15	1463	2	4M00G9D
USOBO-6R	8	66	15	1463	2	4M00G9D
USOBO-7A	8	73	15	1463	2	4M00G9D
USOBO-7R	8	73	15	1463	2	4M00G9D
USOBO-8A	8	87.5	15	1463	2	4M00G9D
USOBO-8R	8	87.5	15	1463	2	4M00G9D
USOBO-9A	8	94	15	1463	2	4M00G9D
USOBO-9R	8	94	15	1463	2	4M00G9D
USOBO-10A	8	130.6	15	1463	2	4M00G9D
USOBO-10R	8	130.6	15	1463	2	4M00G9D
USOBO-11A	8	139	15	1463	2	4M00G9D
USOBO-11R	8	139	15	1463	2	4M00G9D
P92-3	9, 20	-10		5000	-3, 11	4M00G7W
P92-4	9, 20	-13		5000	-3, 12	4M00G7W
P92-5	9, 20	-141		5000	-3, 13	4M00G7W
P92-6	9, 20	-144		5000	-3, 14	4M00G7W
P92-7	9, 20	-30.4	15	5000	-3, 15	4M00G7W
P92-8	9, 20	92	15	5000	-3, 16	4M00G7W
P92-9	9, 20	110	15	5000	-3, 17	4M00G7W
FLTSATCOM-C E ATL-2	11, 13	-15.5		630	-4	4M00W9D
FLTSATCOM-C E PAC-1	11, 13	-105		630	-4	4M00W9D
FLTSATCOM-C E PAC-2	11, 13	-100		630	-4	4M00W9D
FLTSATCOM-C INDOC-1	11, 13	29		630	-4	4M00W9D
FLTSATCOM-C INDOC-2	11, 13	72		630	-4	4M00W9D
FLTSATCOM-C INDOC-3	11, 13	75		630	-4	4M00W9D
FLTSATCOM-C W PAC-1	11, 13	172		630	-4	4M00W9D
FLTSATCOM-C W PAC-2	11, 13	-177		630	-4	4M00W9D
IRIS-10A	11, 13	29	20	630	-4	4M00W9D
IRIS-11A	11, 13	125	20	630	-4	4M00W9D
IRIS-1A	11, 13	-105	20	630	-4	4M00W9D
IRIS-2A	11, 13	-100	20	630	-4	4M00W9D
IRIS-3A	11, 13	-22.5	20	630	-4	4M00W9D
IRIS-4A	11, 13	-15.5	20	630	-4	4M00W9D
IRIS-5A	11, 13	72	20	630	-4	4M00W9D
IRIS-6A	11, 13	75	20	630	-4	4M00W9D
IRIS-7A	11, 13	172	20	630	-4	4M00W9D

ITU Designation	SGLS Channel(s)	GSO Location (deg)	C/N (dB)	Noise Temp (K)	Max Gain (dBi)	Emission Designation
IRIS-8A	11, 13	-177	20	630	-4	4M00W9D
IRIS-9A	11, 13	-145	20	630	-4	4M00W9D
USGCSS PH3 E PAC-2	12, 16	-130		877	-4.5	4M00G2D
USGCSS PH3 INDOC	12, 16	60		877	-4.5	4M00G2D
USGCSS PH3 INDOC-2	12, 16	57		877	-4.5	4M00G2D
USGCSS PH3 MID-ATL	12, 16	-42.5		877	-4.5	4M00G2D
USGCSS PH3 W PAC	12, 16	175		877	-4.5	4M00G2D
USGCSS PH3 W PAC-2	12, 16	180		877	-4.5	4M00G2D
USGCSS PH3B ATL	12, 16	-12	15	877	-4.5	4M00G2D
USGCSS PH3B E PAC	12, 16	-135	15	877	-4.5	4M00G2D
USGCSS PH3B E PAC-2	12, 16	-130	15	877	-4.5	4M00G2D
USGCSS PH3B INDOC	12, 16	60	15	877	-4.5	4M00G2D
USGCSS PH3B INDOC-2	12, 16	57	15	877	-4.5	4M00G2D
USGCSS PH3B MID-ATL	12, 16	-42.5	15	877	-4.5	4M00G2D
USGCSS PH3B W ATL	12, 16	-52.5	15	877	-4.5	4M00G2D
USGCSS PH3B W PAC	12, 16	175	15	877	-4.5	4M00G2D
USGCSS PH3B W PAC-2	12, 16	180	15	877	-4.5	4M00G2D
USGCSS PH3B W PAC-3	12, 16	150	15	877	-4.5	4M00G2D
USGOVSAT-10	12, 16	60	20	800	-4.5	4M00G2D
USGOVSAT-11R	12, 16	150	20	630	-4	4M00G2D
USGOVSAT-12	12, 16	175	20	630	-4	4M00G2D
USGOVSAT-13R	12, 16	-121.9	20	630	-4	4M00G2D
USGOVSAT-14R	12, 16	-77	20	630	-4	4M00G2D
USGOVSAT-16R	12, 16	24	20	630	-4	4M00G2D
USGOVSAT-18R	12, 16	78.5	20	630	-4	4M00G2D
USGOVSAT-19R	12, 16	86	20	630	-4	4M00G2D
USGOVSAT-1R	12, 16	180	20	630	-4	4M00G2D
USGOVSAT-20R	12, 16	134	20	630	-4	4M00G2D
USGOVSAT-2R	12, 16	-151	20	800	-4.5	4M00G2D
USGOVSAT-3R	12, 16	-135	20	800	-4.5	4M00G2D
USGOVSAT-4R	12, 16	-130	20	800	-4.5	4M00G2D
USGOVSAT-5R	12, 16	-112	20	800	-4.5	4M00G2D
USGOVSAT-6R	12, 16	-52.5	20	800	-4.5	4M00G2D
USGOVSAT-7R	12, 16	-42.5	20	800	-4.5	4M00G2D
USGOVSAT-8	12, 16	-12	20	800	-4.5	4M00G2D
USGOVSAT-9R	12, 16	57	20	800	-4.5	4M00G2D
FLTSATCOM-C E ATL-1	13	-22.5		630	-4	4M00W9D
MILSTAR 1	13, 14	-90		630	-4	4M00G2D
MILSTAR 13	13, 14	4		630	-4	4M00G2D
MILSTAR 14	13, 14	177.5		630	-4	4M00G2D
MILSTAR 4	13, 14	55		630	-4	4M00G2D
MILSTAR 5	13, 14	90		630	-4	4M00G2D
MILSTAR 6	13, 14	-120		630	-4	4M00G2D
MILSTAR 8	13, 14	-68		630	-4	4M00G2D
USGAE-1	13, 14	-90	20		-4	2M90G2D
USGAE-10	13, 14	-150	20	630	-4	2M90G2D
USGAE-10R	13, 14	-150	20	630	-4	2M90G2D
USGAE-11	13, 14	93	20	630	-4	2M90G2D
USGAE-11M	13, 14	93	20	630	-4	2M90G2D
USGAE-12	13, 14	111	20	630	-4	4M00G2D
USGAE-12M	13, 14	111	20	630	-4	4M00G2D
USGAE-13	13, 14	96	20	630	-4	4M00G2D
USGAE-13M	13, 14	96	20	630	-4	4M00G2D

ITU Designation	SGLS Channel(s)	GSO Location (deg)	C/N (dB)	Noise Temp (K)	Max Gain (dBi)	Emission Designation
USGAE-14	13, 14	-16.5	20	630	-4	4M00G2D
USGAE-14M	13, 14	-16.5	20	630	-4	4M00G2D
USGAE-15	13, 14	-31.5	20	630	-4	4M00G2D
USGAE-15M	13, 14	-31.5	20	630	-4	4M00G2D
USGAE-16	13, 14	30	20	630	-4	4M00G2D
USGAE-16R	13, 14	30	20	630	-4	4M00G2D
USGAE-17	13, 14	-39	20	630	-4	4M00G2D
USGAE-17R	13, 14	-39	20	630	-4	4M00G2D
USGAE-18	13, 14	-155	20	630	-4	4M00G2D
USGAE-18M	13, 14	-155	20	630	-4	4M00G2D
USGAE-19	13, 14	150	20	630	-4	4M00G2D
USGAE-2	13, 14	4	20	630	-4	2M90G2D
USGAE-20	13, 14	155	20	630	-4	4M00G2D
USGAE-21	13, 14	175	20	630	-4	4M00G2D
USGAE-22	13, 14	180	20	630	-4	4M00G2D
USGAE-23M	13, 14	19	20	630	-4	4M00G2D
USGAE-3	13, 14	90	20	630	-4	2M90G2D
USGAE-3M	13, 14	90	20	630	-4	2M90G2D
USGAE-4	13, 14	177.5	20	630	-4	2M90G2D
USGAE-5	13, 14	55	20	630	-4	2M90G2D
USGAE-5M	13, 14	55	20	630	-4	2M90G2D
USGAE-6	13, 14	-120	20	630	-4	2M90G2D
USGAE-6M	13, 14	-120	20	630	-4	2M90G2D
USGAE-7	13, 14	-68	20	630	-4	2M90G2D
USGAE-7M	13, 14	-68	20	630	-4	2M90G2D
USGAE-8	13, 14	-9	20	630	-4	2M90G2D
USGAE-8M	13, 14	-9	20	630	-4	2M90G2D
USGAE-9	13, 14	152	20	630	-4	2M90G2D
USGAE-9R	13, 14	152	20	630	-4	2M90G2D

4.2.1.2 LTE System Parameters

The information in this section is taken from the CSMAC Working Group 1 report regarding LTE System parameters[6], relevant details are included in this report.

The information regarding LTE Uplink Characteristics is intended for use in general analysis of the potential for harmful interference between commercial LTE operations and Federal Government operations in the 1755-1850 MHz band. The information represents a collaborative effort between industry and government representative experts to agree on LTE parameters that are closer to realistic operational parameters than have been used in past analysis. However, because these parameters will be used in general analysis, it is not possible to fully capture the parameters that will be observed in an actual deployment, which will vary by carrier implementation and site specific geography. In order to provide a uniform set of information to

[6] Commerce Spectrum Management Advisory Committee, Final Report, Working Group 1- 1695-1710 MHz Meteorological-Satellite, dated 1/22/2013, downloaded from: http://www.ntia.doc.gov/other-publication/2013/csmac-wg-1-final-report-v2.

apply in a wide variety of analysis, a number of simplifying assumptions have been made that may continue to result in analysis showing a greater level of interference that would actually occur. These include, but are not limited to, the assumptions being based on 100% loading rather than a more realistic loading level and use of propagation curves that may result in higher calculated power. In addition, because the transmit power and interference potential of a UE device is highly dependent on the UE distance to a base station, developing and applying UE information that is uncorrelated to interfering path is likely to overestimate the amount of interference. None-the-less, given the difficulty of developing and running a fully correlated model, it was agreed that it is reasonable to proceed with uncorrelated values in order to develop a general understanding of the interference potential given limited time and resources. Analysis based on this information will serve as useful guidance in understanding the potential for systems to coexist and the potential for harmful interference. However, site specific coordination will be necessary to maximize efficient use of the spectrum.

4.2.1.2.1 User Equipment (UE) Transmit Characteristics

4.2.1.2.1.1 Cumulative Distribution Function (CDF) of Total EIRP per Scheduled User Equipment

Assumptions for generation of CDF data:

- LTE Frequency Division Duplex (FDD) system
- 10 MHz LTE Bandwidth
- 100% system loading at LTE Base Station (eNodeB)
    - All Physical Resource Blocks (PRB) are occupied at all times
- 100% outdoor UE distribution
- P_0 = -90 dBm and alpha = 0.8 for UL Power Control (urban/suburban/rural)
- Proportional fair algorithm for LTE Scheduler
- Full-buffer traffic model (i.e. All UEs have data in their Radio Link Control (RLC) layer buffer at all times)

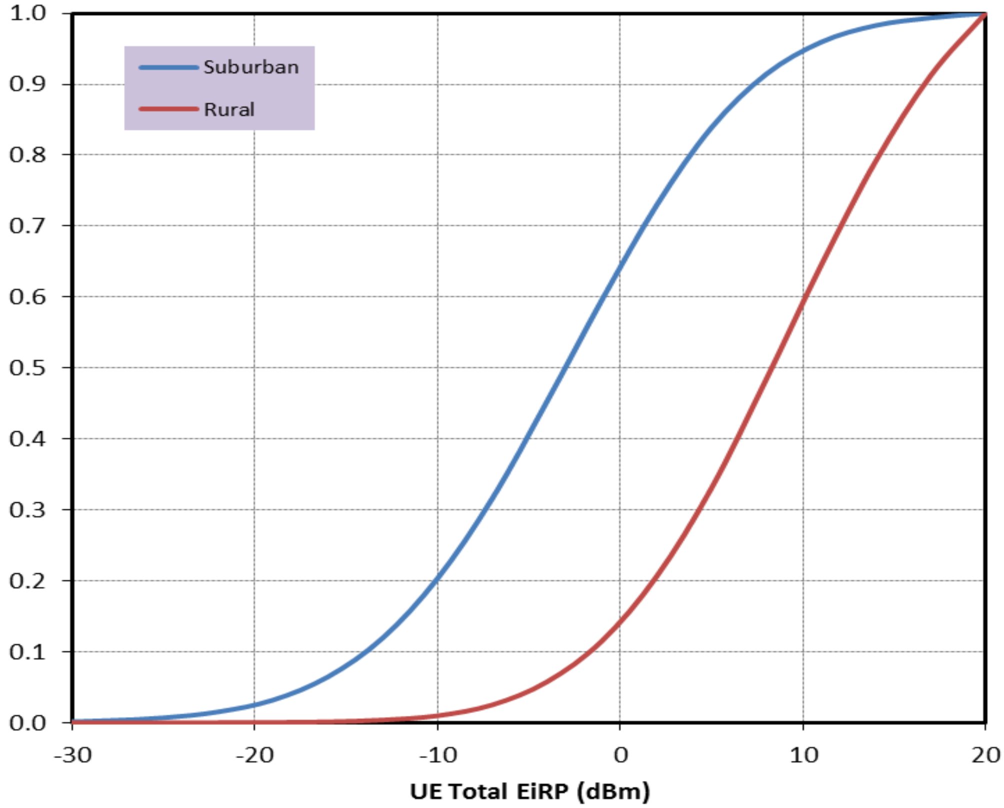


Figure 4.2.1-7: UE EIRP Cumulative Distribution Function.

Table 4.2.1-8: Tabulated UE EIRP Cumulative Distribution Function.

	Urban/Suburban (1.732 Km ISD) (6 UE scheduled/TTI/sector)		Rural (7 Km ISD) (6 UE scheduled/TTI/sector)	
UE EiRP (dBm)	PDF	CDF	PDF	CDF
-40	0.0000	0.0000	0.0000	0.0000
-37	0.0001	0.0001	0.0000	0.0000
-34	0.0002	0.0003	0.0000	0.0000
-31	0.0008	0.0011	0.0000	0.0000
-28	0.0020	0.0031	0.0000	0.0000
-25	0.0040	0.0071	0.0000	0.0000
-22	0.0083	0.0154	0.0002	0.0002
-19	0.0166	0.0320	0.0004	0.0006
-16	0.0327	0.0647	0.0007	0.0013
-13	0.0547	0.1194	0.0026	0.0039
-10	0.0839	0.2033	0.0060	0.0099
-7	0.1128	0.3160	0.0153	0.0252
-4	0.1370	0.4530	0.0325	0.0577
-1	0.1429	0.5959	0.0575	0.1152
2	0.1338	0.7297	0.0911	0.2062
5	0.1094	0.8390	0.1245	0.3307
8	0.0753	0.9143	0.1536	0.4843
11	0.0450	0.9594	0.1605	0.6448
14	0.0236	0.9830	0.1473	0.7920
17	0.0106	0.9936	0.1203	0.9123
20	0.0064	1.0000	0.0877	1.0000

4.2.1.2.1.2 Assumed Number of Scheduled (transmitting) UE per Sector

- Assume Physical Downlink Control Channel (PDCCH) = 6 is typical for a 10 MHz LTE Channel
    - PDCCH contains Downlink Control Information (DCI) blocks, which provide downlink and uplink resource allocations, and power control commands for UEs
    - Use UEs per sector (i.e. the number of simultaneously transmitting UEs is 6 per sector or 18 per eNodeB, for a 10 MHz Channel)
    - 100 % of uplink resources (PRBs) are equally distributed among transmitting UEs in each sector
- Randomly assign power in accordance with UE power CDF for each independent Monte-Carlo analysis trial
- The PDCCH value and corresponding number of UE should be adjusted based on the LTE channel bandwidth:

Table 4.2.1-9: PDCCH Value.

PDCCH Value / Channel Bandwidth			
5 MHz	10 MHz	15 MHz	20 MHz
PDCCH = 3	PDCCH = 6	PDCCH = 9	PDCCH = 12

4.2.1.2.1.3 Requirements for Unwanted Emissions

LTE specification defines requirements for two separate kinds of unwanted emissions, with those for spurious emissions being the more stringent. In addition to these minimum requirements, additional spectrum emission requirements defined in the 3GPP standard must be fulfilled for a specific deployment scenario such as intra-band contiguous Carrier Aggregation, cell handover, UL-MIMO, etc.

4.2.1.2.1.4 RF Spectrum Emissions

4.2.1.2.1.4.1 Out-of-Band Emissions - Spectrum Emissions Mask (SEM)

Out-of-band (OOB) specification is defined with respect to the edge of the occupied bandwidth and it is absolute value.

The 3GPP defines standard identifies two resolution measurement bandwidths (30 kHz and 1 MHz). For example, -15 dBm/30 kHz for $\Delta f_{OOB} \pm$ 0-1 in 5 MHz can be converted to 1 MHz bandwidth resolution results in a limit of 0.23 dBm/1MHz.

For frequencies greater than (Δf_{OOB}) as specified in Table below for Band Class 4, the spurious emissions requirements are applicable.

Table 4.2.1-10: Spectrum Emission Limit (dBm)/ Channel Bandwidth

Δf_{OOB} (MHz)	1.4 MHz	3.0 MHz	5 MHz	10 MHz	15 MHz	20 MHz	Measurement Bandwidth
± 0-1	-10 (5.23)	-13 (2.23)	-15 (0.23)	-18 (-2.77)	-20 (-4.77)	-21 (-5.77)	30 kHz (1 MHz)
± 1-2.5	-13	-13	-13	-13	-13	-13	1 MHz
± 2.5-2.8	-25	-13	-13	-13	-13	-13	1 MHz
± 2.8-5		-13	-13	-13	-13	-13	1 MHz
± 5-6		-25	-13	-13	-13	-13	1 MHz
± 6-10			-25	-13	-13	-13	1 MHz
± 10-15				-25	-13	-13	1 MHz
± 15-20					-25	-13	1 MHz
± 20-25						-25	1 MHz

4.2.1.2.1.4.2 Adjacent Channel Leakage Ratio (ACLR)

ACLR is the ratio of the filtered mean power centered on the assigned channel frequency to the filtered mean power centered on an adjacent channel frequency at nominal channel spacing.

Defines ACLR requirements for two scenarios for an adjacent LTE (Evolved Universal Terrestrial Radio Access (E-UTRA)) channels and/or UMTS channels.

Table 4.2.1-11: The minimum requirement of ACLR for LTE.

	Channel bandwidth / E-UTRA$_{ACLR1}$ / Measurement Bandwidth					
	1.4 MHz	3.0 MHz	5 MHz	10 MHz	15 MHz	20 MHz
E-UTRA$_{ACLR1}$	30 dB	30 dB	30 dB	30 dB	30 dB	30 dB
E-UTRA channel Measurement bandwidth	1.08 MHz	2.7 MHz	4.5 MHz	9.0 MHz	13.5 MHz	18 MHz
Adjacent channel center frequency offset (in MHz)	+1.4 / -1.4	+3.0 / -3.0	+5 / -5	+10 / -10	+15 / -15	+20 / -20

4.2.1.2.1.4.3 Spurious Emissions

Spurious emissions are emissions which occur well outside the bandwidth necessary for transmission and may arise from a large variety of unwanted transmitter effects such as harmonic emission, parasitic emissions, intermodulation products and frequency conversion products, but exclude OOB emissions unless otherwise stated.

This value would be used outside the defined SEM mask.

Table 4.2.1-12: Spurious Emissions.

Frequency Range	Maximum Level	Measurement Bandwidth	Notes
9 kHz ≤ f < 150 kHz	-36 dBm (-6 dBm)	1 kHz (1 MHz)	
150 kHz ≤ f < 30 MHz	-36 dBm (-16 dBm)	10 kHz (1 MHz)	
30 MHz ≤ f < 1000 MHz	-36 dBm (-26 dBm)	100 kHz (1 MHz)	
1 GHz ≤ f < 12.75 GHz	-30 dBm	1 MHz	
12.75 GHz ≤ f < 19 GHz	-30 dBm	1 MHz	Note 1
Note 1: Applies for Band 22, Band 42 and Band 43			

4.2.1.2.2 LTE Base Station Receive Characteristics

This table endeavors herein to provide an overview of Base Station Receiver characteristics established by international standards. While the characteristics can be used in a preliminary analysis of the potential for harmful interference from Government operations to commercial operations there are numerous implementation specific methods that a carrier can deploy to significantly impact the potential for harmful interference. Examples include, but are not limited to antenna down tilt, antenna orientation, power control to improve link margin, temporal use of specific channels to avoid using channels during periods when harmful interference is likely, and use of natural terrain to provide shielding. Section 4.2.1.2.3provides a more detailed discussion of the potential impact of antenna down tilt and orientation. Because these features are implementation specific it is difficult to include them as part of a general analysis and specific features should not be included as part of final rules. While a general analysis may be useful in determining the overall viability as to whether some form of sharing is possible, rules should not include a defined exclusion or coordination zone that precludes commercial deployments in a given area based on the potential for harmful interference to the commercial operation. Instead, as much information as possible regarding the government operations should be provided, thus allowing the commercial licensee to determine the most effective method to mitigate harmful interference.

Table 4.2.1-13: LTE (FDD) Base Station Receiver Characteristics

Parameter	Base Station	
Receiver Channel Bandwidth (MHz)	1.4, 3, 5, 10, 15 and 20 With signal bandwidths of 1.08, 2.7, 4.5, 9, 13.5 and 18 MHz	
Adjacent Channel Selectivity (ACS)	Channel BW Wide Area BS	Wide Area BS Wanted Signal Mean Power (dBm)
	1.4 MHz 3 MHz 5 MHz 10 MHz 15 MHz 20 MHz	-95.8 ($P_{REFSENS}$ + 11dB) -95.0 ($P_{REFSENS}$ + 8dB) -95.5 ($P_{REFSENS}$ + 6dB) -95.5 ($P_{REFSENS}$ + 6dB) -95.5 ($P_{REFSENS}$ + 6dB) -95.5 $P_{REFSENS}$ + 6dB
	Reference TS 36.104 Table 7.5.1-3	Interfering signal mean power: -52 dBm [7]
	Channel BW Local Area BS	Local Area BS Wanted Signal Mean Power (dBm)
	1.4 MHz 3 MHz 5 MHz 10 MHz 15 MHz 20 MHz	-87.8 ($P_{REFSENS}$ + 11dB) -87.0 ($P_{REFSENS}$ + 8dB) -87.5 ($P_{REFSENS}$ + 6dB) -87.5 ($P_{REFSENS}$ + 6dB) -87.5 ($P_{REFSENS}$ + 6dB) -87.5 ($P_{REFSENS}$ + 6dB)
	Reference TS 36.104 Table 7.5.1-4	Interfering signal mean power: -44 dBm [8]
Noise Figure (dB)	5	
Reference Sensitivity (dBm) $P_{REFSENS}$ for Wide Area BS [9]	1.4 MHz 3 MHz	-106.8 -103.0

Notes:

[7] This interfering signal mean power is for a wanted signal mean power at P_REFSENS + xdB (where x=6dB for 3-20MHz channels and 11dB for 1.4MHz channel). One way to interpret this spec is that this is the maximum interference level for xdB desense criterion. For instance, if 1dB desense is used in the coexistence studies, a conversion can be done to adjust for the lower desense criterion. For example, if adjacent channel selectivity is specified as -52dBm and wanted signal mean power is P_REFSENS + 6dB, the level can be adjusted by 11dB for the smaller sensitivity degradation allowed giving -52-11= -63dBm:

- 1 dB desense: maximum interference = Noise floor - 5.87 dB

[8] Same as in footnote i, interfering signal mean power can be adjusted for 1dB desense if this criterion is used in the coexistence studies. For example, in the case of wanted signal mean power at P_REFSENS + 6dB, the level can be adjusted by 11dB for the smaller sensitivity degradation allowed giving -44-11=-55dBm.

[9] See 3GPP TS 36.104, §7.2. $P_{REFSENS}$ is the power level of a single instance of the reference measurement channel. This requirement shall be met for each consecutive application of a single instance of FRC A1-3 mapped to disjoint frequency ranges with a width of 25 resource blocks each.

Parameter	Base Station	
	5 MHz	-101.5
	10 MHz	-101.5
	15 MHz	-101.5
	20 MHz	-101.5
Reference Sensitivity (dBm) $P_{REFSENS}$ for Local Area BS	1.4 MHz	-98.8
	3 MHz	-95.0
	5 MHz	-93.5
	10 MHz	-93.5
	15 MHz	-93.5
	20 MHz	-93.5
Antenna Gain (Mainbeam) (dBi) [10, 11, 12]	18	
Azimuth Off-Axis Antenna Pattern (dBi as a function of off-axis angle in degrees)	ITU-R Recommendation F.1336-3 with an elevation 3 dB beamwidth of 10 degrees, k=0.2 and the equations in Section 3.2[vi]	
Elevation Off-Axis Antenna Pattern (dBi as a function of off-axis angle in degrees)	ITU-R Recommendation F.1336-3 with an elevation 3 dB beamwidth of 10 degrees, k=0.2 and the equations in Section 3.2[vi]	
Antenna Polarization	Linear	
Antenna Height (meters) [1]	30 (Urban/Suburban) 15 to 60 (Rural)	
Antenna Azimuth 3 dB Beamwidth (degrees) [2]	70	
Antenna Down Tilt Angle (degrees)	3	
Cable, Insertion, or Other Losses (dB)	2	
Interference Criterion	1dB desense. This translates into a maximum interference = Noise floor - 5.87 dB (I/N= ~ -6dB).	

Note 1: For single entry analysis the maximum antenna height of 45 meters for base stations will be used for rural. For aggregate analysis antenna heights will be varied between the minimum and maximum values shown in the table.

Note 2: A base station typically has three sectors each 120 degrees wide.

4.2.1.2.2.1 Assumed Inter-Site Distance (ISD) for Generic LTE eNodeB Deployment

---

[10] Base station antennas, both receive and transmit, typically have strongly angle-dependent gain characteristics characterized by a horizontal and vertical beamwidth. The gain value listed here corresponds to the maximum gain corresponding to the main lobe of the antenna.

[11] Assuming full bore-sight gain of the LTE BS receive antenna (18dBi) may not reflect interference mitigation techniques as would be naturally deployed. Significant interference mitigation can be achieved via several factors, which are standard in the industry: e.g., antenna downtilts (point below the horizon, achieved by either mechanical and/or electrical means), antenna azimuth orientation (orient away from the interferer), and use of available terrain (where it exists) for additional refraction loss, etc. This needs to be taken into account when doing interference studies. The antenna techniques are further discussed in the Annex.

[6] See Annex 8 of ITU-R Recommendation F.1336-3, which observes that the recommended equations for antenna gains often do not accurately reflect the gains of actual antennas – particularly with regard to the side lobes, as indicated in Figs 24 to 27 in Annex 8. This should be taken account when considering interference in directions far from the main antenna lobe.

Use concentric circles centered around metropolitan area unless other site specific assumptions are agreed upon.

Urban/suburban area assumed to be 30 km radius with rural area covering outer circle up to 100 km, unless other site specific assumptions are mutually agreed upon.

Surrounding rural deployment may be adjusted by mutual agreement if and when there is more than one urban/suburban area within 100 km of the site being analyzed.

Table 4.2.1-14: LTE (FDD) Base Station Receiver Characteristics

Deployment	ISD	eNodeB Antenna Height	UE Antenna Height
Urban/Suburban (r <= 30 km)	1.732 km	30 m	1.5 m
Rural (U/S Edge < r <= 100 km)	7 km	45 m	1.5 m

4.2.1.2.3 Annex Example: Interference Mitigation via Antenna Downtilting and Antenna Azimuth Orientation

Commercial cellular deployments do regularly take into account interference considerations. Even inter-cell interference within the same service provider network typically results in finite antenna downtilt, particularly for systems with full spectral reuse (i.e., 3G, 4G). Also in the commercial cellular world there exist numerous instances where adjacent band and other interference scenarios have been successfully mitigated via proper RF design (e.g., between service providers in adjacent spectrum, etc).

To illustrate the potentially significant impact of these antenna techniques on the interference issues, we evaluate two representative commercial base station antennas from CommScope/Andrew in the discussion below. Depending on the Federal Government systems involved, different assumptions might be appropriate.

- Andrew HBX-6516DS-T0M: 18 dBi max gain (along the main beam or "bore sight" direction), 65° horizontal beamwidth, 0° electrical downtilt, 7.1° vertical beamwidth.
- Andrew HBX-9016DS-T0M: 18.3 dBi max gain, 90° horizontal beamwidth, 0° electrical downtilt, 4.8° vertical beamwidth.

Using these antennas, and orienting them with a 60° azimuthal offset from the Federal Government system direction, the gain reductions for various reasonable antenna downtilts are calculated (in the table, the gain reductions listed below are with respect to the max ~18dBi gain of these antennas). The displayed gain reductions as a function of the downtilt angles are for the case of an interferer at the horizon. Note that an interference source like JTRS may be at an elevation (e.g., the WG-5 draft calculation assumed 10,000 feet), which would result in higher gain reductions.

Table 4.2.1-15: Gain reduction examples.

Antenna	Gain reduction from 60° azimuthal orientation	Gain reduction from 4° vertical downtilt [Total reduction from azimuth + downtilt]	Gain reduction from 6° vertical downtilt [Total reduction from azimuth + downtilt]	Gain reduction from 8° vertical downtilt [Total reduction from azimuth + downtilt]
Andrew HBX-6516DS-T0M	8.6 dB	2.8 dB [11.4 dB]	7.4 dB [16.0 dB]	16.3 db [24.9 dB]
Andrew HBX-9016DS-T0M	6.3 dB	8.7 dB [15.0 dB]	26.9 dB [33.2 dB]	24.1 dB [30.4 dB]

As can be seen, total gain reductions (summing the reductions due to azimuthal orientation plus those from vertical downtilt) can be very large, anywhere from 11.4 to 30.4 dB – assuming the Federal Government interfering transmitter is at the horizon in our example.

4.2.2 Satellite Orbital Statistics Evaluation

Satellite systems will schedule operations based on need to communicate with each satellite system and on the time that a particular satellite is in view of the earth terminal. In the evaluation of sharing between mobile broadband and Satellite earth terminal transmissions this section evaluates the time that a satellite may be able to receive TT&C commands, we note that procedures in DoD Instruction 3100.2 indicate that routine satellite TT&C is to be performed on the same channels as mission data operations, therefore it can be expected that for some systems the need to use the SGLS channels may be reduced.[13]

This satellite orbital statistical analysis indicates that, based on data in the ITU SNS Database, there will be a significant amount of time slots where there will not be any satellite earth terminal transmissions on particular channels.

Some observations from this analysis indicate the follow aspects relevant in sharing:

If a satellite has a near polar orbit then there will be significant periods of time that the satellite will be at low elevations and the satellite will be at all azimuth angle from the satellite earth terminal.

Duration of any satellite pass[14], can be on the order of minutes for satellites at low altitudes. For satellites at high altitudes, the duration of communication is longer.

4.2.2.1 Modeling Method

The mathematical model for prediction of satellite position and velocity using NORAD "two-line elements" is based on the SGP – C Library. This orbital model was used to evaluate the time that

[13] DoD Instruction Number 3100.12, Subject: Space Support, September 14, 2000.

[14] A satellite pass is contiguous time of which the satellite is above the minimum elevation angle for communications.

a satellite is above a minimum elevation angle recommend for this evaluation for this section. Based on SGLS operational parameters the minimum elevation angle is 3 degrees.

By simulating the satellite system and recording the elevation angle and azimuth angle, along with the time period when the satellite is above the minimum elevation can provide an indication of when it is possible to communicate with a satellite. This will provide an upper limit to how often a channel issued but not provide a complete analysis as it is unusual for TT&C operations to occur at every SGLS uplink location for every satellite pass.

The orbital model used in this analysis considered a satellite in a spherical orbit over a spherical earth and does not consider other factors such as drag of the atmosphere or other similar effects that are used in more accurate orbital models.

4.2.2.2 Model Results

Each system was evaluated over a 1 year time frame and sampled at 1 second increments in time. Shown in Figure 4.2.2-1 is the results for pointing direction of the earth terminal during a simulation of each individual system on channel 1 at the Ft. Belvoir, VA location (38.7411N, -77.3726E) for satellite listed in Table 4.2.2-1.[15] The data is aggregated in 1 degree increments for elevation and azimuth from the location of the earth terminal and the vertical axis is the number of 1 second increment at which the satellite is at the particular azimuth / elevation angle. The convention is that due north is zero degree azimuth with due east being 90 degrees azimuth.

Table 4.2.2-1: NGSO System data for SGLS Channel 1.

ITU Designation	SGLS Channel	Number of Satellites	Inclination (deg)	Apogee (km)	Perigee (km)	C/N (dB)	Noise Temp (K)	Max Gain (dBi)	Emission Designation
USKW	1	1	98	630	630	15	288	6	4M00G9D
USPOJOAQUE	1	1	40	600	600	15	290	2	2M00G1D
USYV	1	1	99	900	900	15	630	3	4M00G9D

[15] Note that one of the satellite systems, L-92, has an option of operating on any of 4 channels in the SGLS band and is not evaluated here, consideration should be given if this system can operate in band not being used by mobile broadband systems.

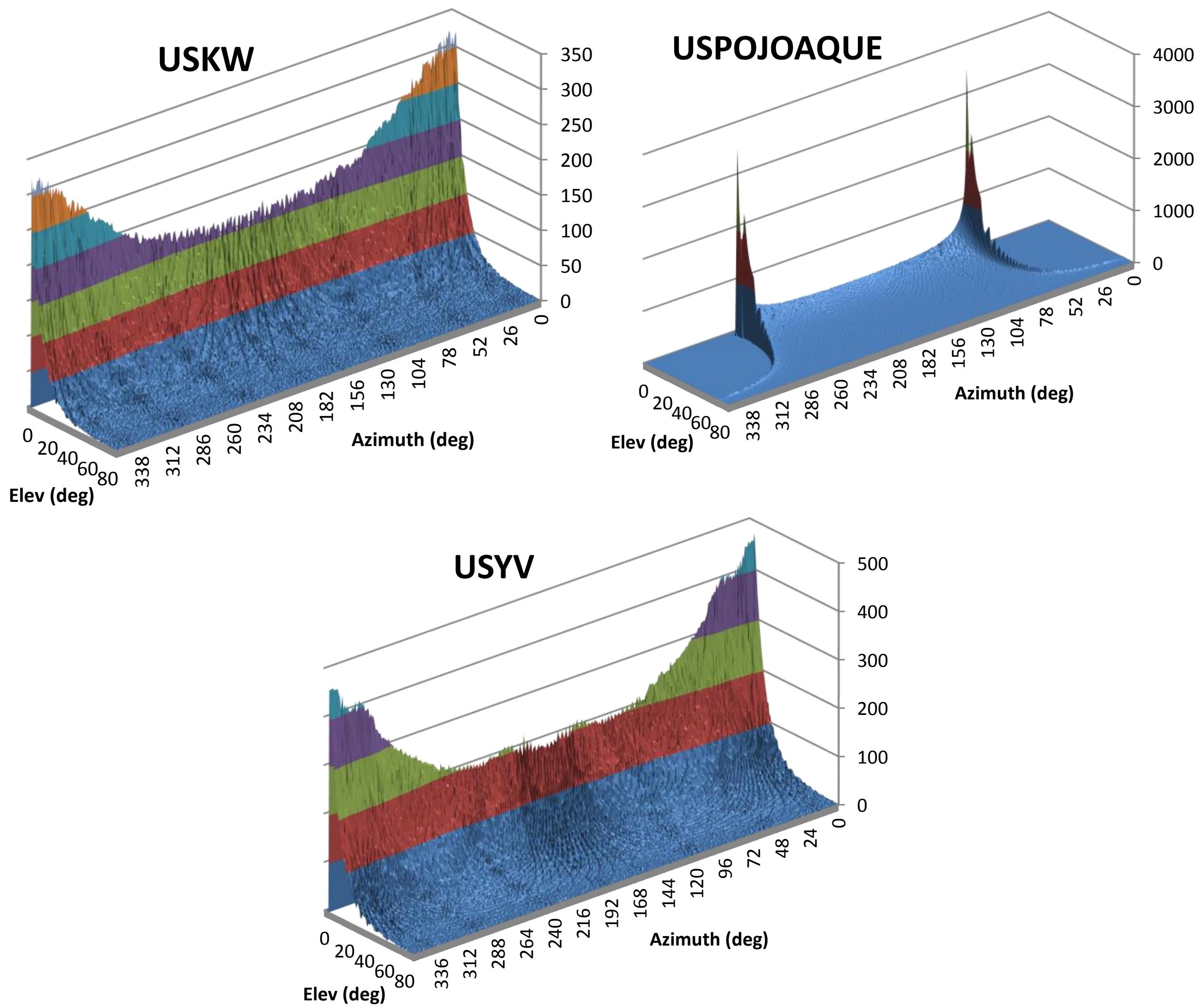


Figure 4.2.2-1: Ft. Belvoir channel 1 Azimuth / Elevation histogram.

Shown in Figure 4.2.2-2 is the histogram of how long a satellite is continuously above the minimum elevation angle (i.e. length of a satellite pass) and the histogram between satellite passes for each of the constellations. As these are low earth orbiting satellites the length of a satellite pass is relative short, while the time between passes can be relatively long. It should be noted that actual TT&C operations will be driven jointly by all satellites that can potentially use a channel and the need to perform TT&C operations to that satellite.

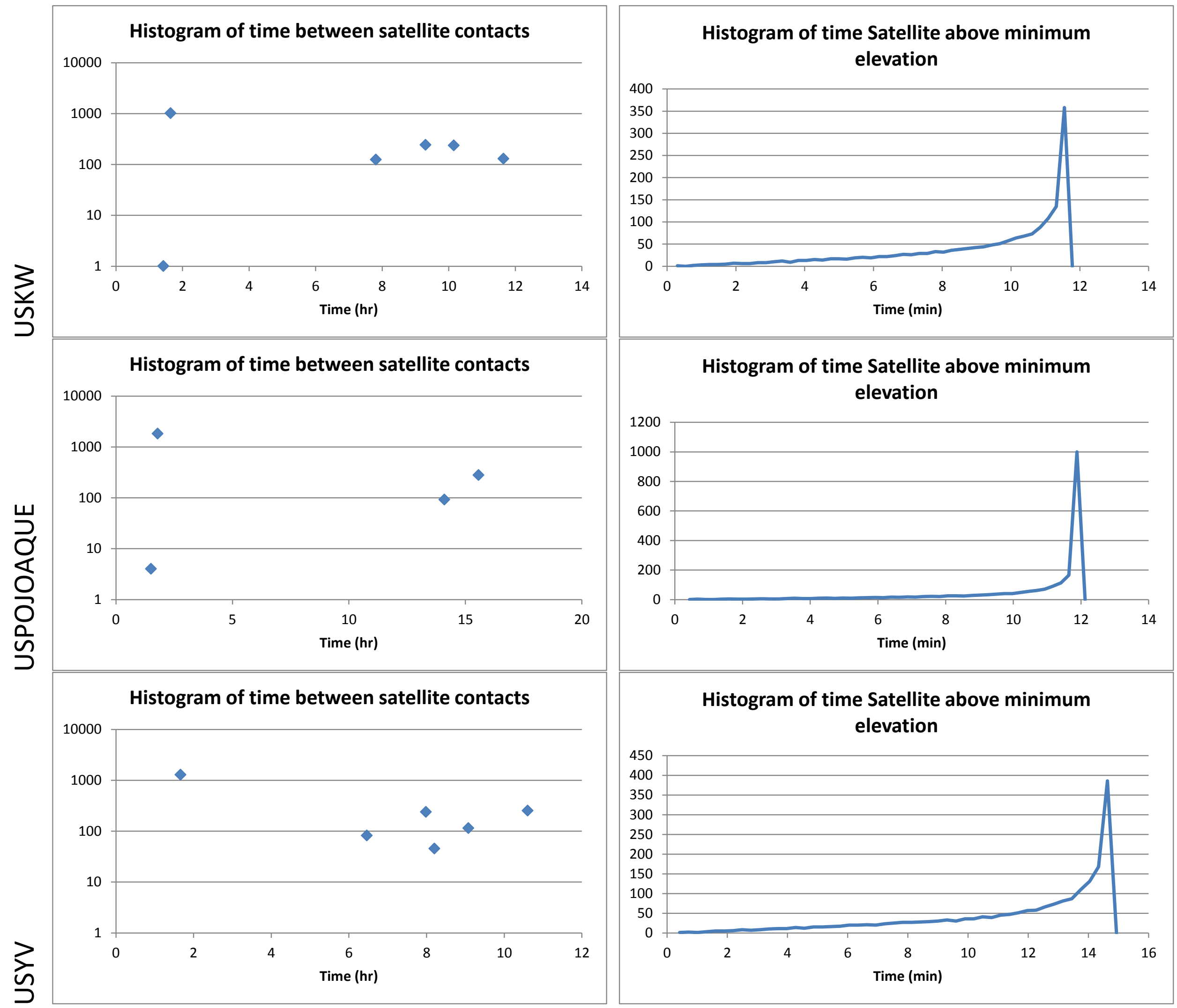


Figure 4.2.2-2: Ft. Belvoir channel 1 satellite pass information.

To Illustrate how location can impact this data, shown in Figure 4.2.2-3 is the results for pointing direction of the earth terminal during a simulation of each individual system on channel 1 at the Prospect Harbor, ME location (44.4067N, -68.0128E) for satellites listed in Table 4.2.2-1.[16] While the near polar orbit satellites (USKW and USYV, with high inclination angels) have very similar charts, the USPOJOAQUE chart indicates the earth terminal will be pointing south during contacts, this is due to the inclination of the satellite being lower.

[16] Note that one of the satellite systems, L-92, has an option of operating on any of 4 channels in the SGLS band and is not evaluated here, consideration should be given if this system can operate in band not being used by mobile broadband systems.

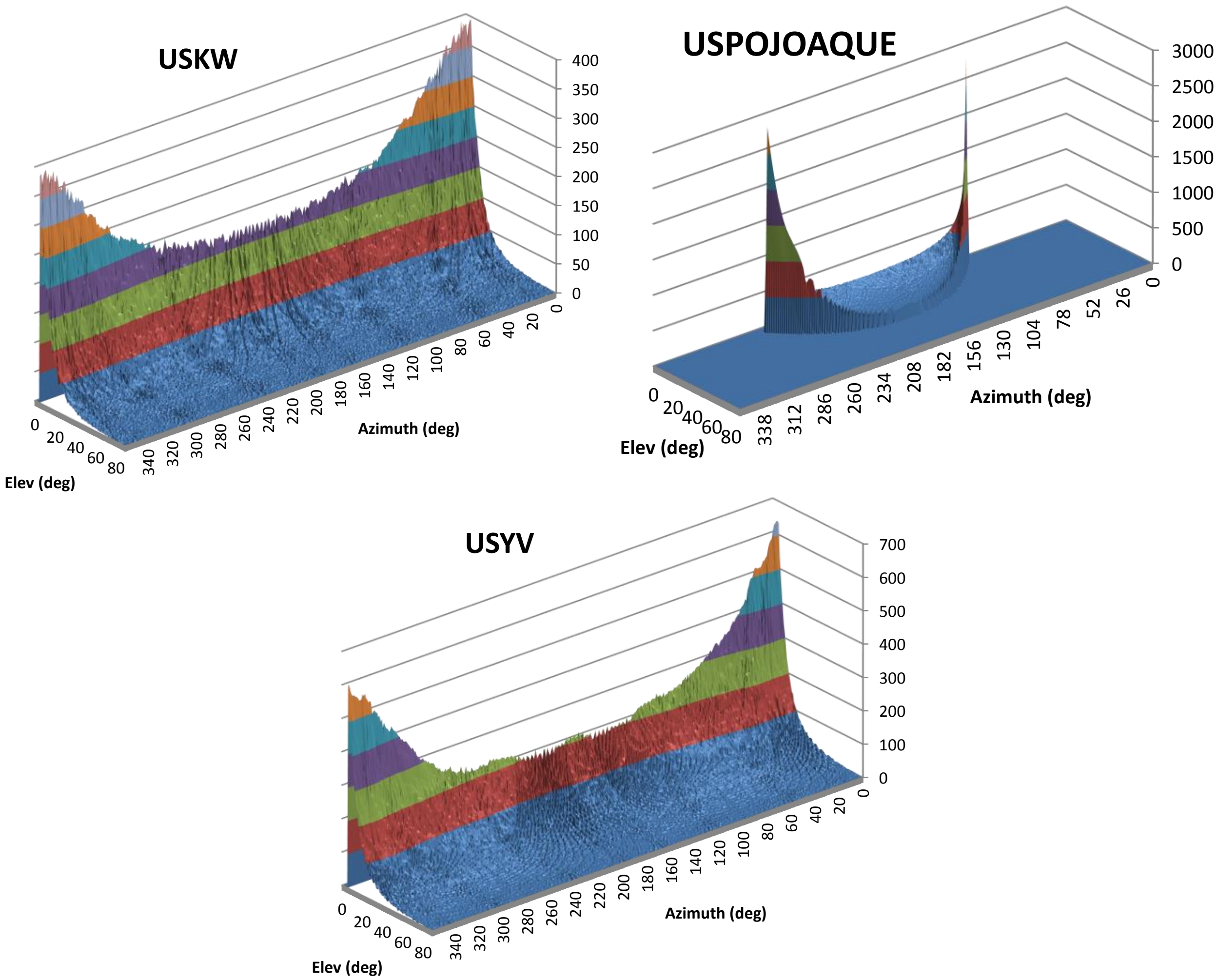


Figure 4.2.2-3: Prospect Harbor channel 1 Azimuth / Elevation histogram.

Shown in Figure 4.2.2-4 is the histogram of how long a satellite is continuously above the minimum elevation angle (i.e. length of a satellite pass) and the histogram between satellite passes for each of the constellations. There is little difference due to the location of the earth terminal.

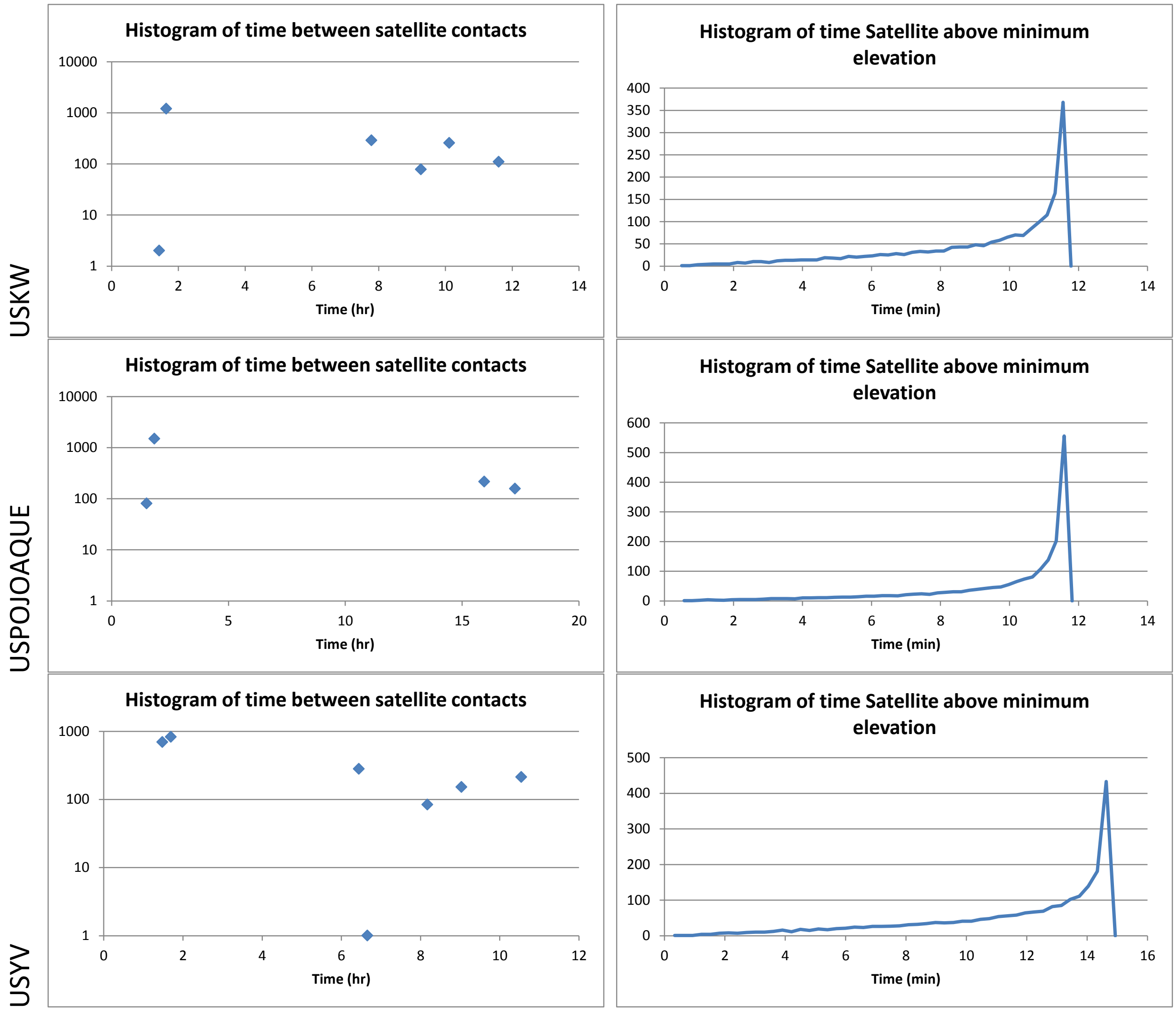


Figure 4.2.2-4: Prospect Harbor channel 1 satellite pass information.

4.2.3 Phase 1 Analysis of interference into LTE Base Station Receivers

4.2.3.1 Introduction / Summary

Operational factors such as the percentage of time Satellite Operation (SATOPS) antennas spend at low elevations, the exact channel usage statistics, the use of power control and other various operational factors will impact the level of interference received by LTE base stations (BS). Phase 1 of this analysis will use assumptions based on information that can be provided in a public form, along with assumptions based the ITU registration data of the satellite systems, to provide representative guidance on the level of interference around a SATOPS uplink that may be received by a LTE base station. The key assumptions made in this document are listed in Table 4.2.3-1. Phase 2 of this study will present results based on the same methodology but will be based on confidential operational parameters that will not be made public as part of this report. The results of phase 2 can be found in section 4.2.4.

Section 4.2.3.2 provides a full description of the interference analysis methodology, key assumptions and results. Section 4.2.5 discusses mitigation methods and other associated factors that can be implemented to reduce the impact of harmful interference from SATOPS into base station receivers.

Based on the analysis presented in Phase 1 of this analysis, the CSMAC WG 3 proposes the following recommendations be adopted by the full CSMAC.

Recommendation 4.2.3-1: NTIA should direct federal earth station operators to document in their transition plans publicly releasable information to allow prospective licensees to understand the potential impact to any base station receivers from SATOPS uplinks. Detailed information to be provided by the federal users should include:

- Contours within which radiated power levels from federal earth stations is likely to exceed the -137.4 dBW LTE interference threshold (1 dB desense) assuming worst case conditions of maximum transmit power at minimum elevation angle.
- Contours within which radiated power levels from federal earth stations is likely to remain below the -137.4 dBW LTE interference threshold (1 dB desense) as calculated at 100%, 99%, and 95% of the time assuming nominal operating conditions, based on recent historical use. Usage of federal earth stations can and will change with time, and is not limited by the information provided.

Recommendation 4.2.3-2: NTIA should recommend that the FCC, in consultation with the NTIA, consider methods to allow government agencies to share with commercial licensees information relevant to spectrum sharing in the vicinity of federal earth stations, subject to appropriate non-disclosure or other agreements, consistent with US law and government policies.

Recommendation 4.2.3-3: The space operations service (Earth-to-space) remains a primary service in the 1761 – 1842 MHz band, as defined in Government footnote G42.

Recommendation 4.2.3-4: NTIA should recommend the FCC require that commercial licensees accept interference from federal SATOPS earth stations operating in the 1761-1842 MHz band.

Recommendation 4.2.3-5: NTIA should direct federal earth station operators to identify and document in their transition plans the cost and schedule required to accelerate and/or expand the transition of all federal earth stations to radiate a narrower bandwidth signal.

4.2.3.2 Interference Assessment

SATOPS model data given in Table C-4 of the interim report indicates that the SATOPS ground stations are capable of emitting very high EIRP at low elevation angles. When these ground stations are located in a geographic area containing LTE systems the high EIRP can cause harmful interference to LTE base stations. The percentage of time that these emissions take place is based on the methods described in this section.

4.2.3.2.1 Key Assumptions

The evaluation in this document makes several assumptions regarding the operational parameters of SATOPS and deployment parameters of LTE systems. The key assumptions used in the evaluation are shown in Table 4.2.3-1.

Table 4.2.3-1: Interference Impact Assumptions

SATOPS Assumptions
Distribution of pointing angles, down to minimum elevation of 3 degrees
Distribution of SATOPS channel usage
Parameters listed in Section 4.2.3.2.2.2.1
Spherical symmetry of antenna patterns
No more than 2 uplinks occur at any one time
4.004 MHz emission bandwidth
SATOPS operate at a range of power levels, both maximum and minimum power levels will be evaluated
LTE Assumptions
Minimum channel use of 2x5 MHz, band of use will be Base Station receive
Parameter of operation as listed in Section 4.2.3.2.2.2.2

More complete information could provide a more accurate analysis of SATOPS interference impact on LTE could include data on:

- Distribution of SATOPS elevation angles
- Distribution of SATOPS channel usage
- Distribution of SATOPS EIRP in time taking into account the use of power control

4.2.3.2.2 Evaluation

4.2.3.2.2.1 Interference Computation

The interference power levels at the BS system receiver are calculated using the equation below for each SATOPS uplink being considered in the analysis:

$$I = EIRP + G_R - L_T - L_R - L_P - L_L - FDR$$

where:

I:	Received interference power at the output of the BS receiver antenna (dBm)
EIRP:	Equivalent isotropically radiated power (EIRP) of the SATOPS uplink station (dBm)
G_R:	Antenna gain of the BS receiver in the direction of the SATOPS uplink station (dBi)
L_R:	BS insertion loss (dB)
L_P:	Propagation loss between BS and SATOPS uplink station (dB)
L_L:	Building and non-specific terrain losses (dB)
FDR:	Frequency dependent rejection (dB)

The FDR will be applied for two cases, one in which the BS channel overlaps with the SATOPS channel (co-channel case). The other case is an adjacent channel, for this situation it is assumed that the SATOPS channel begins at the edge of the BS channel, the FDR for adjacent channel operation is derived below in section 4.2.3.2.2.4.

Using the equation above, the values of interference power level are calculated for each SATOPS uplink transmitters being considered in the analysis. These individual interference power levels are then used in the calculation of the aggregate interference to the BS system receivers using the equation below:[17]

$$I_{AGG} = 10 \log \left[\sum_{j=1}^{N} I_j \right] + 30$$

where:

I_{AGG}:	Aggregate interference to the BS system receiver from the SATOPS transmitters (dBm)
N:	Number of SATOPS transmitters
I_j:	Interference power level at the input of the base station receiver from the j^{th} SATOP transmitter (Watts)

4.2.3.2.2.2 Input Parameters

4.2.3.2.2.2.1 SATOPS

The input parameters for satellite terminals used in this analysis are found in section 4.2.1.1 of this report.

4.2.3.2.2.2.2 Base Station

The base station characteristics are found in section 4.2.1.2 of this report.

4.2.3.2.2.2.3 Propagation Model

For this analysis two models are evaluated, the modified Hata-Model and the ITM model used in point-to-point mode.

4.2.3.2.2.2.4 Modified Hata-Model

This is a radio propagation model that extends the urban Hata Model (which in turn is based on the Okumura Model) to cover a more elaborated range of frequencies.[18]

The modified Hata-Model is formulated for 1 500 MHz < $f \leq$ 2 000 MHz as[19],

---

[17] The interference power calculated from each SGLS uplink must be converted from dBm to Watts before calculating the aggregate interference seen by the BS system receiver.

[18] Final report for COST Action 231, Chapter 4

792 *Case 1*: $d \leq 0.04$ km

$$L = 32.4 + 20\log(f) + 10\log\left(d^2 + \frac{(H_b + H_m)^2}{10^6}\right)$$

793 *Case 2*: $d \geq 0.1$ km

794 *Sub-Case 1: Urban*

795
$$L = 46.3 + 33.9\log(f) - 13.82\log(\max\{30, H_b\}) + \left[44.9 - 6.55\log(\max\{30, H_b\})\right]\log(d)^{\alpha} - a(H_m) - b(H_b)$$

796 *Sub-case 2*: *Suburban*

$$L = L(urban) - 2\{log[(f/28)]\}^2 - 5.4$$

797 *Sub-case 3*: *Open area*

$$L = L(urban) - 4.78\{log[(f)]\}^2 + 18.33\ log(f) - 40.94$$

798 *Case 3*: 0.04 km $< d < 0.1$ km

799
$$L = L(0.04) + \frac{\left[\log(d) - \log(0.04)\right]}{\left[\log(0.1) - \log(0.04)\right]}\left[L(0.1) - L(0.04)\right]$$

[19] Report ITU-R SM.2028-1.

When L is below the free space attenuation for the same distance, the free space attenuation should be used instead

where

$L =$	Median path loss. (dB)
$f =$	Frequency of Transmission. (MHz)
$H_B =$	Base Station Antenna effective height. (m)
$d =$	Link distance. (km)
$H_m =$	Mobile Station Antenna effective height. (m)
$a(H_m) =$	Mobile station Antenna height correction factor as described in the Hata Model for Urban Areas.

$$a(H_m) = (1.1\log(f) - 0.7)\min\{10,\ H_m\} - (1.56\log(f) - 0.8) + \max\{0,\ 20\log(H_m/10)\}$$

$$b(H_b) = \min\{0,\ 20\log(H_b/30)\}$$

Note that for short range devices in the case of low base station antenna height, H_b, $b(H_b) = \min\{0,\ 20\log(H_b/30)\}$ is replaced by:

$$b(H_b) = (1.1\ log(f) - 0.7)min\{10, H_b\} - (1.56\log(f) - 0.8)$$

$$+max\left(0, 20\ log(H_b/10)\right)$$

$$\propto = \begin{cases} 1 & d \le 20\ km \\ 1 + (0.14 + 1.87x10^{-4}f + 0.00107H_b)\left(\log\left(\frac{d}{20}\right)\right)^{0.8} & 20\ km < d\ \le 100\ km \end{cases}$$

4.2.3.2.2.2.5 ITM Model

The ITS model of radio propagation for frequencies between 20 MHz and 20 GHz (the Longley-Rice model) (named for Anita Longley & Phil Rice, 1968) is a general purpose model that can be applied to a large variety of engineering problems. The model, which is based on electromagnetic theory and on statistical analyses of both terrain features and radio measurements, predicts the median attenuation of a radio signal as a function of distance and the variability of the signal in time and in space.[20]

This analysis will use the ITM model in point-to-point mode with the parameters shown below in Table 4.2.3-2.

[20] See http://www.its.bldrdoc.gov/resources/radio-propagation-software/itm/itm.aspx

Table 4.2.3-2: ITM Parameters.

Parameter	Selected	Options
Polarization	Vertical	Vertical Horizontal
Radio climate	Contental subtropical	Equatorial Contental subtropical Maritime tropical Desert Contental Temperate Maritime temperate, over land Maritime temperate, over sea
Dielectric constant of ground	15 – Average Ground	4- Poor ground 15 - Average ground 25 - Good ground 81 - Fresh/sea water
Conductivity of ground	0.005 - Average ground	0.001 - Poor ground 0.005 - Average ground 0.02 - Good ground 0.01 - Fresh water 5.00 - Sea water
Reliability statistic values	50%	Greater than zero, less than 100%
Confidence statistic values	50%	Greater than zero, less than 100%
Surface Refractivity	301 - Contental Temperate (Use for Avg. Atmospheric Conditions)	280 - Desert (Sahara) 301 - Contental Temperate (Use for Avg. Atmospheric Conditions) 320 - Continental Subtropical (Sudan) / Maritime Temperate, Over Land (UK and Contenital West Coast) 350 - Maritime Temperate, Over Sea 360 - Equatorial (Congo) 370 - Maritime Subtropical (West Coast of Africa)
Terrain Database	GLOBE – 30 Second[21]	

4.2.3.2.2.3 Interference Criteria

The interference criteria for the BS is found in Section 4.2.3.2.2.2.2, for this analysis results will be shown for a 1 dB desense level and for a 3 dB desense level to provide a representative for cases in which licenses would be willing to accept more interference from SATOPS operations than the baseline interference criteria.

---

[21] The GLOBE 30 second terrain data can be downloaded from the following website http://www.ngdc.noaa.gov/mgg/topo/gltiles.html.

A wide area BS has a reference sensitivity of -101.5 dBm. A 1 dB desense interference criteria occurs at an interference level of -101.5-5.87 = 107.37 dBm. A 3 dB desense interference occurs at an interference level of -101.5 dBm.

4.2.3.2.2.4 Adjacent channel FDR

In order to consider adjacent channel interference there are two interference mechanisms to be considered: interfering transmitter unwanted emission and receiver filtering imperfection.[22]

To analyze the combined effect of these two interference mechanism, we adopt the analytical methodology that is widely used by ITU-R[23] and 3GPP[24]. First, the two interference mechanisms are modeled by the following two parameters:

- Adjacent Channel Leakage Ratio (ACLR) (transmitter unwanted emission mechanism) is the portion of interfering Tx power which leaks into the victim Rx channel (integrated over the Rx channel bandwidth). ACLR is thus a measure of the transmitter performance. Power received by the victim receiver due to unwanted emission can be represented by P/ACLR, where P is the transmitted power.
- Adjacent Channel Selectivity (ACS) (receiver filtering mechanism) is the portion of Tx power which is picked up from the interferer Tx by the overlap of the victim receiver filter with the Tx bandwidth. ACS is thus a measure of the receiver performance. Power received by the victim receiver due to receiver filtering imperfection can be represented by P/ACS.

---

[22] Inter-System MWA MS to MWA MS Coexistence analysis in 3.5 GHz Band for Unsynchronized TDD systems or TDD adjacent to FDD systems, Annex 5, Doc. SE19(06)70, Source: Motorola, 17 November 2006.

[23] Coexistence between IMT-2000 time division duplex and frequency division duplex terrestrial radio interface technologies around 2 600 MHz operating in adjacent bands and in the same geographical area. http://www.itu.int/itudoc/itu-r/publica/rep/m/2030.html.

[24] WiMAX Forum, "Sharing studies in the 2 500-2 690 MHz band between IMT-2000 and broadband wireless access (BWA) systems," ITU-R WP8F/597, October 2005.

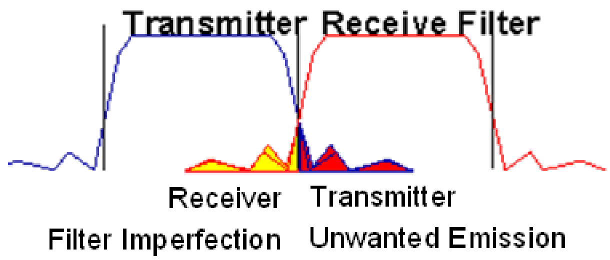


Figure 4.2.3-1: Adjacent channel interference mechanisms.

The combined interference power of these two mechanisms, *I*, can be written as

$$I = \frac{P}{ACLR} + \frac{P}{ACS} = P\left(\frac{1}{ACLR} + \frac{1}{ACS}\right)$$

Therefore,

$$\frac{P}{I} = \frac{1}{\frac{1}{ACLR} + \frac{1}{ACS}}$$

This ratio is termed Adjacent Channel Interference Ratio (ACIR) and can be ex*press*ed as:

$$ACIR = \frac{1}{\frac{1}{ACS} + \frac{1}{ACLR}}$$

ACIR is therefore defined as the ratio of the transmission power to the interference power measured after a receiver filter in the victim channels. It should be emphasized that when one of the two factors is much smaller than the other, *ACIR* will be dominated by the smaller one. In such case, the larger factor can be omitted.

Sections 4.2.3.2.2.4.1 and 4.2.3.2.2.4.2 compute the ACLR for the transmitting SATOPS terminals using a spectrum mask that is commonly expected to be used with-in 3-5 years and the legacy mask that is currently in common use.

The adjacent/alternate channel rejection performance is typically measured using the following procedure. First, the BER performance is measured at receiver sensitivity without any interference. Then the desired signal strength is raised 6 dB above the rate dependent receiver sensitivity, and power level of the interfering signal is raised until the same BER is obtained. The power difference between the interfering signal and the desired channel is the corresponding adjacent/alternate channel rejection depending on the frequency location of the interference signal. In other words, we want to obtain same performance (e.g., BER, FER) when operating at Sensitivity without interference, and when operating at Sensitivity+6dB in presence of interference. Therefore, the following Equation holds.

$$SNR_{\min} = \frac{Sensitivity}{N} = \frac{\left[Sensitivity + 6dB\right]}{N + \frac{P}{ACS}} = \frac{2 \bullet Sensitivity}{N + \frac{P}{ACS}}$$

where P = interference power and N is the noise power.

Based on the above Equation, ACS can be expressed as:

$$\begin{aligned} ACS &= \frac{P}{N} \\ &= SNR_{\min} + 6dB + Adjacent\ /\ Alternate\ Channel\ Rejection \end{aligned}$$

The relationship between ACS, SNR_{min} (or $P_{REFSENS}$), and Adjacent/alternate channel rejection are illustrated in the following figure.

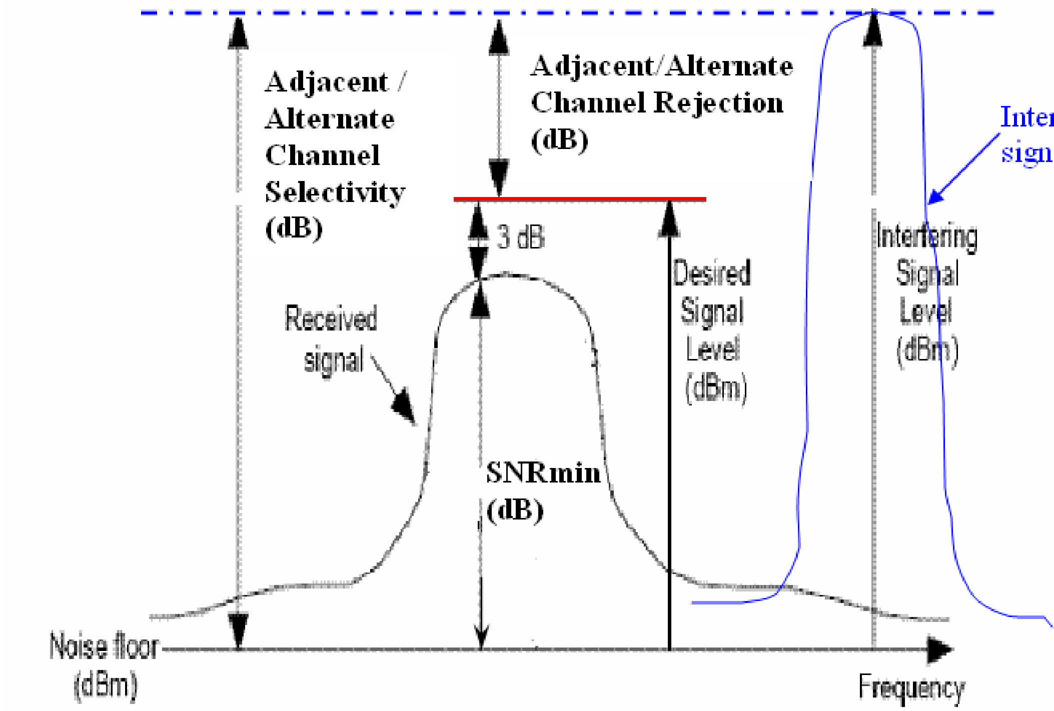


Figure 4.2.3-2: Illustration of ACS, SNRmin and Adjacent/Alternate channel rejection.

Using the Parameters provided for the LTE BS in section 4.2.1.2 the ACS for a 5 or 10 MHz channel is computed to be $ACS = -95.5 + (-95.5 - (-52)) = 52$ dB.

4.2.3.2.2.4.1 Spectrum Mask Commonly used in the Future

For the analysis of the interference from SATOPs into LTE base stations in an adjacent channel the measured data shown in Figure 4.2.1-3 is used. It is the understanding that these new 225 kHz width AFSCN signals will be commonly used within 3 to 5 years. The signals will use 440 channels with a 160 kHz separation. To study the scenario of adjacent channel interference it is assumed that the LTE system can be directly adjacent to the AFSCN uplink signal in the frequency space (0 MHz offset) or at larger offsets.

For the calculation of the attenuation in the adjacent spectrum, the measured AFSCN signal is approximated by the following reference spectrum mask.

Table 4.2.3-3: Reference mask to calculate attenuation in adjacent channel.

Distance from channel edge	Attenuation [dB]
Channel edge	-8
1 MHz	-46
2 MHz	-77
5 MHz	-80

Figure 4.2.3-3 shows the defined reference spectrum mask in red. This mask will be used to calculate the attenuation in the adjacent 5 and 10 MHz. With defining this reference spectrum mask, it is guaranteed that the measured signal is below the mask all the time.

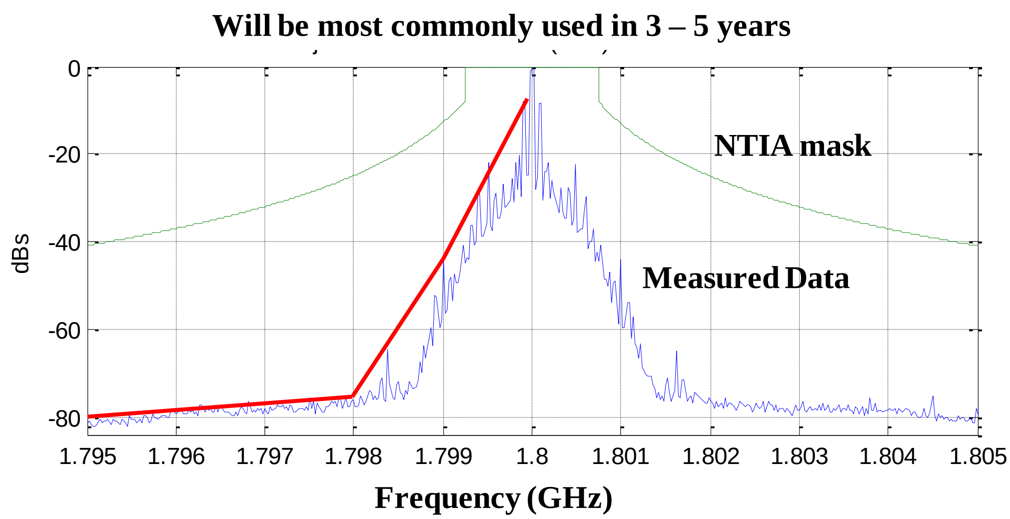


Figure 4.2.3-3: Reference mask to calculate attenuation in adjacent channel.

The attenuation in the adjacent channel is now calculated integration of the transmitter mask over the 5 MHz and 10 MHz LTE victim receive channel. The results for 0 MHz, 1 MHz and 2 MHz offset from channel edge are shown in Table 4.2.3-4, other offsets are shown in Figure 4.2.3-4.

Table 4.2.3-4: ACLR for typical AFSCN emissions.

Offset	**5 MHz LTE channel**	**10 MHz LTE channel**
0 MHz	15.7 dB	15.7 dB
1 MHz	53.0 dB	53.0 dB
2 MHz	71.9 dB	69.4 dB

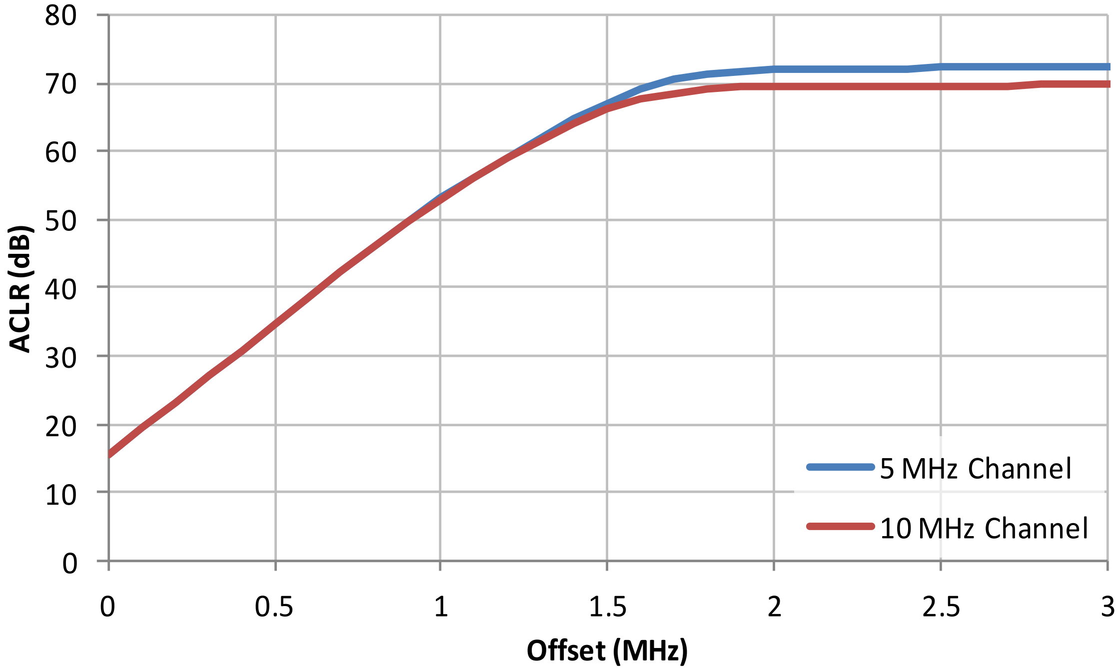


Figure 4.2.3-4: ACLR for Typical AFSCN emissions.

Based on the above results, the ACIR values are found in Table 4.2.3-5 and Figure 4.2.3-5.

Table 4.2.3-5: ACIR for typical AFSCN emissions.

Offset	5 MHz LTE channel	10 MHz LTE channel
0 MHz	15.7 dB	15.7 dB
1 MHz	49.5 dB	49.5 dB
2 MHz	52 dB	51.9 dB

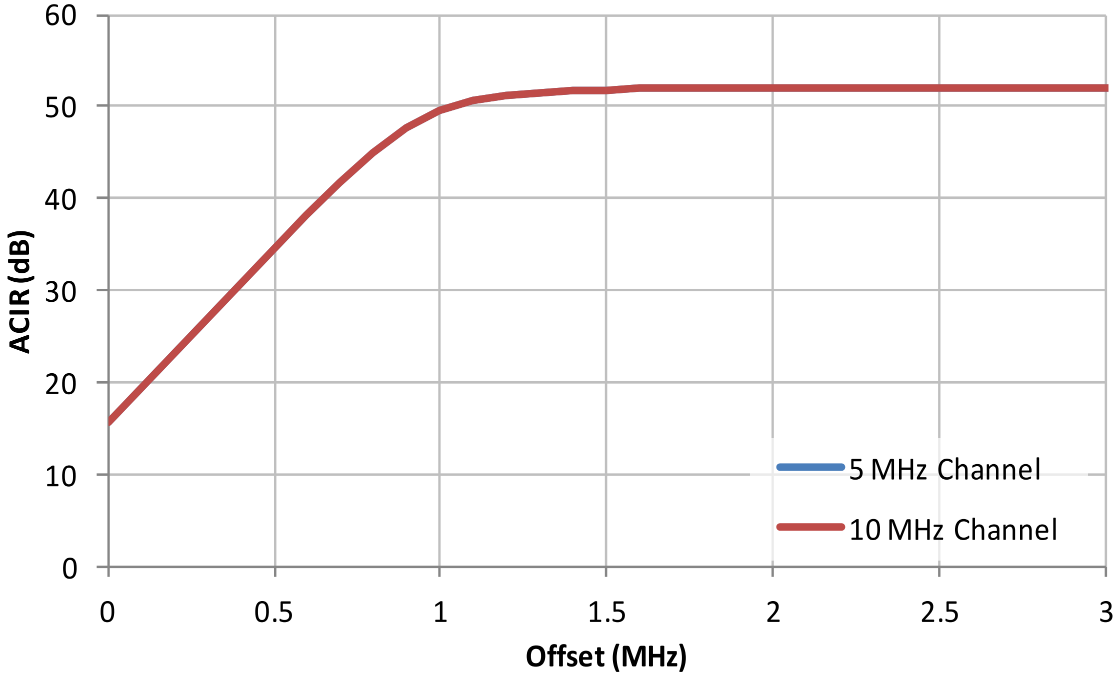


Figure 4.2.3-5: ACIR for Typical AFSCN emissions.

4.2.3.2.2.4.2 Legacy Spectrum Mask

Additionally, the legacy spectrum mask, which is currently used in current AFSCN terminals, is also considered in this adjacent channel analysis. This mask is to be understood as a worst case scenario and is shown in Figure 4.2.1-4.

As for the previous spectrum mask, the mask is approximated by a reference spectrum mask over the frequency range of 1785-1800 MHz by the maximum of $[SF * f_a(x)]$ and $[SF * f_b(x)]$. In which:

$$f_a(x) = (x - 1800) * \sum_{i=-8}^{8} f_2(x - 1800 + 1.6878i)$$

$$f_b(x) = 5.05e - 8 * x + 1.615e - 6$$

Where

x – Frequency in MHz

$f_1(y)$ – Mask represented by Table 4.2.3-6

$f_2(y)$ – Mask represented by Table 4.2.3-7

SF – Scale factor to ensure total power in mask is equal to 1, computed by $\int max\left(f_a(x), f_b(x)\right)dx$

Table 4.2.3-6: Mask $f_1(y)$ to calculate attenuation in adjacent channel.

y (MHz)	Attenuation [dB]
0	0
-1.6878	0
-3.3756	-12
-5.0634	-19
-6.7512	-23
-8.439	-33
-10.1268	-37
-11.8146	-41
-13.5024	-43
-16	-45

Table 4.2.3-7: Mask $f_2(y)$ to calculate attenuation in adjacent channel.

y (MHz)	Attenuation [dB]
-30	-85
-0.6	-85
-0.4	-20
-0.2	-5
0	0
0.2	-5
0.4	-20
0.6	-85
30	-85

Figure 4.2.3-6 shows the defined reference legacy spectrum mask in red. This mask will be used to calculate the attenuation in the adjacent 5 and 10 MHz starting at the channel edge at an offset of 2.002 MHz from the center frequency.

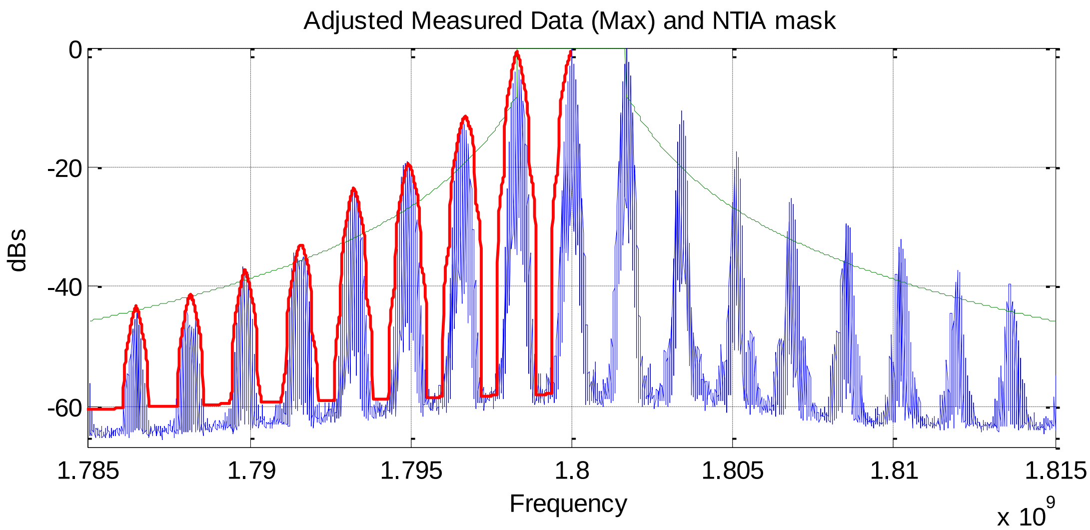


Figure 4.2.3-6: Reference mask to calculate attenuation in adjacent channel.

The attenuation in the adjacent channel is now calculated by integrating the mask over the 5 MHz and 10 MHz LTE victim receive channel. The results for 0 MHz, 1 MHz, 2 MHz and 3 MHz offset are shown in Table 4.2.3-8, other offsets are show in Figure 4.2.3-7.

Table 4.2.3-8: ACLR for Legacy Mask.

Offset	5 MHz LTE channel	10 MHz LTE channel
0 MHz	13.7 dB	13.7 dB
1 MHz	14.5 dB	14.4 dB
2 MHz	22.0 dB	21.9 dB
3 MHz	23.5 dB	23.4 dB

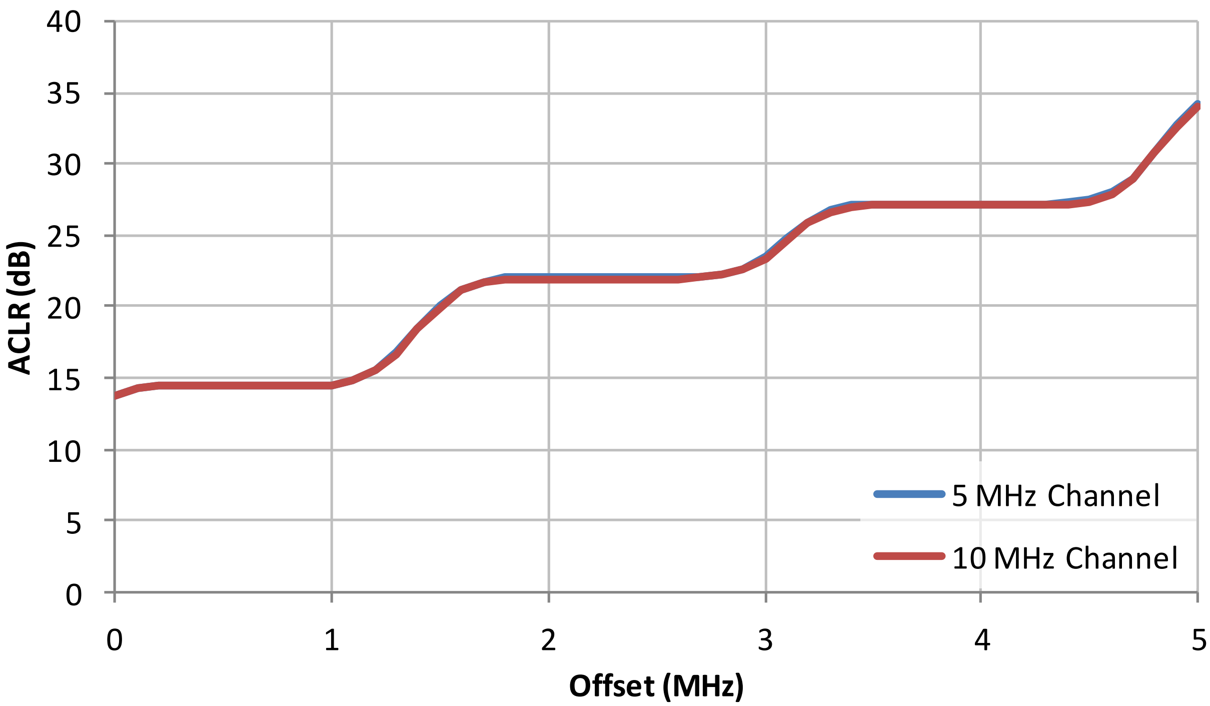


Figure 4.2.3-7: Legacy AFSCN ACLR.

Based on the above results the ACIR values are below in Table 4.2.3-9 and Figure 4.2.3-8.

Table 4.2.3-9: ACIR for Legacy Mask.

Offset	5 MHz LTE channel	10 MHz LTE channel
0 MHz	13.7 dB	13.7 dB
1 MHz	14.5 dB	14.4 dB
2 MHz	22.0 dB	21.9 dB
3 MHz	23.5 dB	23.4 dB

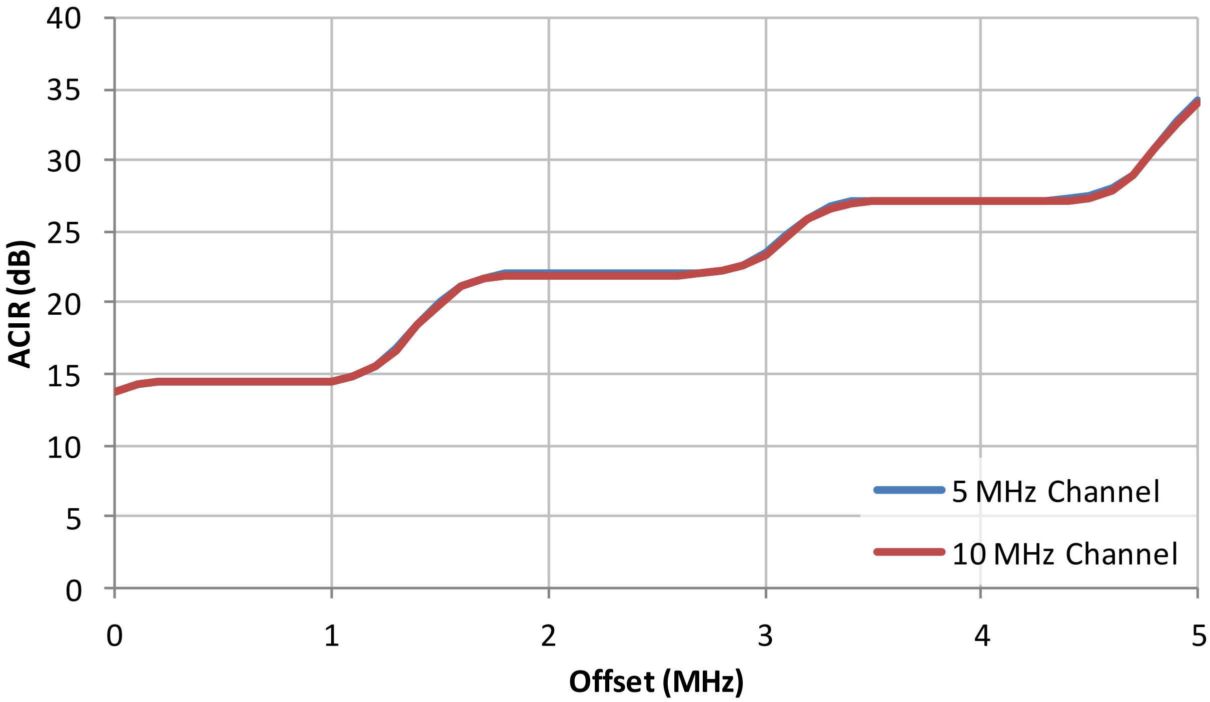


Figure 4.2.3-8: Legacy AFSCN ACIR.

4.2.3.2.2.5 Consideration of BS pointing angles

This analysis will consider three options for the base station pointing angle, one in which the base station is pointed in the direction of the SATOPS transmitter with 3 degrees downtilt using the ITU-R antenna masks (baseline) and the two others in which the base station is pointed 60 degrees away from a vector from the BS to the SATOPS transmitter with either the ITU-R pattern or a representative antenna pattern.

Table 4.2.3-10: BS Scenarios considered in this analysis.

Scenario	Pointing direction	BS Antenna Pattern	Note
Baseline	Directly at SATOPS transmitter	ITU-R F.1336-3 18 dBi max gain 70° azimuth 3 dB beamwidth 10° elevation 3 dB beamwidth 3° downtilt	All the figures will show the baseline case by a blue line
Opt 1	60 degrees away from vector between BS and SATOPS transmitter	ITU-R F.1336-3 18 dBi max gain 70° azimuth 3 dB beamwidth 10° elevation 3 dB beamwidth 3° downtilt	All the figures will show the Opt 1 case by a yellow line
Opt 2	60 degrees away from vector between BS and SATOPS transmitter	Andrew HBX-9016DS-T0M 18.3 dBi max gain 90° azimuth 3 dB beamwidth 4.8° elevation 3 dB beamwidth 8° downtilt	All the figures will show the Opt 2 case by a red lie

4.2.3.2.2.6 Satellite Assumptions

4.2.3.2.2.6.1 Satellite Orbit Model

The mathematical model for prediction of satellite position and velocity using NORAD "two-line elements" is based on the SGP – C Library.[25] This library implements five mathematical models: SGP, SGP4, SDP4, SGP8 and SDP8 and are described in the Spacetrack report No. 3.[26] For this analysis the SGP model will be used.

4.2.3.2.2.6.2 SATOPS Pointing Angles

The analysis will consider the below scenarios in Table 4.2.3-11 for the SATOPS pointing angle.

Table 4.2.3-11: SATOPS Antenna Pointing Scenarios considered in this analysis.

Scenario	Comment
A – Assume SATOPS antenna is always pointing at minimum elevation angle	This is worst case scenario and is not representative of the time varying factors, nor is this representative of the actual point angles for some satellite systems (see section 4.2.2 on satellite pointing angles).
B – Assume SATOPS antenna is always pointing at selected satellite	Will need to consider statistical representation of interference expected to be received.

4.2.3.2.3 Results

4.2.3.2.3.1 Case A – Minimum Elevation Angles

The below in Table 4.2.3-12 are the results for the NHS Location using Modified Hata Propagation. Note that for the Baseline the 3 degree of down tilt does not significantly reduce the antenna gain towards the horizon.

[25] http://www.brodo.de/space/sgp/.

[26] Spacetrack Report No. 3 - Models for Propagation of NORAD Element Sets. Felix R. Hoots, Ronald L. Roehrich, TS Kelso. December 1988. Available at http://www.celestrak.com

Table 4.2.3-12: Modified Hata Propagation model for NHS location.

SATOPS Parameters	Baseline	Opt 1	Opt 2
Tx Frequency (MHz)	1762	1762	1762
Tx Power (dBm)	68.6	68.6	68.6
Peak Antenna Gain (dBi)	45	45	45
Antenna Gain @ Horizon (dBi) (3 deg elev)	16	16	16
EIRP @ Horizion (dBm)	84.6	84.6	84.6
Antenna Height (m)	30	30	30
BS Parameters			
Antenna Height (m)	30	30	30
Down tilt (deg)	3	3	8
3dB Beamwidth (elevation) (deg)	10	10	4.8
Off Azimuth direction (deg)	0	60	60
3dB Beamwidth (azimuth) (deg)	70	70	90
Insertion Loss (dB)	2	2	2
Peak Antenna Gain (dBi)	18	18	18.2
Gain at Horizon (dBi)	18.0	6.5	-12.4
Ref Sen (dBm)	-101.50	-101.50	-101.50
Interference @ 1 dB desense (dBm)	-107.37	-107.37	-107.37
Interference @ 3 dB desense (dBm)	-101.50	-101.50	-101.50
Loss Required for			
1 dB desense (dB)	207.94	196.51	177.54
3 dB desense (dB)	202.07	190.64	171.67
Modified Hata Model separation distance			
Urban case distance (1 dB desense) (km)	102.3	82.7	54.1
Suburban case distance(1 dB desense) (km)	124.4	103.1	71.4
Open area case distance (1 dB desense) (km)	165.6	141.4	104.8
Urban case distance (3 dB desense) (km)	92.0	73.3	46.2
Suburban case distance(3 dB desense) (km)	113.3	92.8	62.6
Open area case distance (3 dB desense) (km)	153.0	129.6	94.4

Figure 4.2.3-10 shows the distances at which a BS would receive interference at a prescribed level, in this case 1 dB desense, when located in the area around the earth terminal. For this figure the ITM model in point-to-point mode and the Modified Hata Model is used to compute loss. The contours are computed by distributing BS within a distance of 200 km around the Satellite uplink terminal in a hexagonal grid with inter-site distance between BS of 7 km, see Figure 4.2.3-9, each red marker is a location of a BS at which the interference level is computed. In Figure 4.2.3-10 the blue line is for the Baseline case, the yellow line is for the Opt 1 case and the red line is for the Opt 2 case. The circles are the corresponding 1 dB desense curves for the Modfied Hata model as computed above in Table 4.2.3-12.

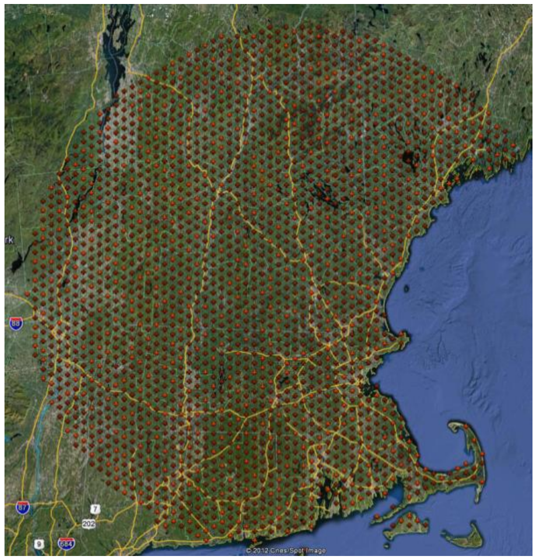
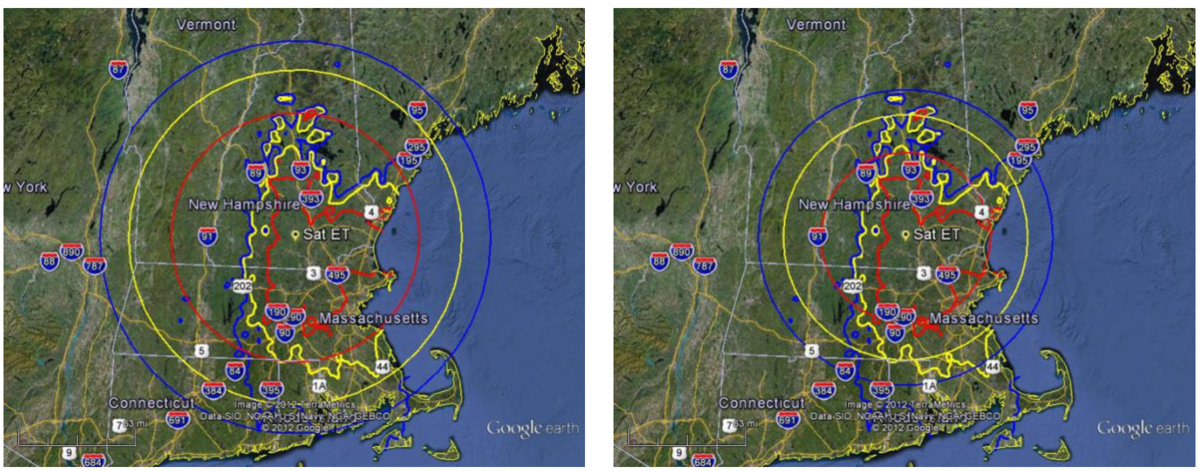


Figure 4.2.3-9: Distribution of BS with 7 km spacing around NHS site (2281 locations).



ITM Model and modified Hata for Open Area Case

ITM Model and modified Hata for Surburban Case

Figure 4.2.3-10: NHS Site 1 dB desense curves.

As can be seen in the figures the impact of terrain around the SATOPS site will have a significant impact regarding the distance at which a BS will receive harmful interference. For that reason the remainder of the analysis will be based on the ITM model.

4.2.3.2.3.1.1 Co Channel Operations

When considering co-channel operations the specific band plan will indicate which channels are co-frequency and which channels are adjacent. Shown in Figure 4.2.3-11 is the representation of 5 MHz blocks with the SGLS channels being the numbered channels and the commercial channels being the lettered channels.

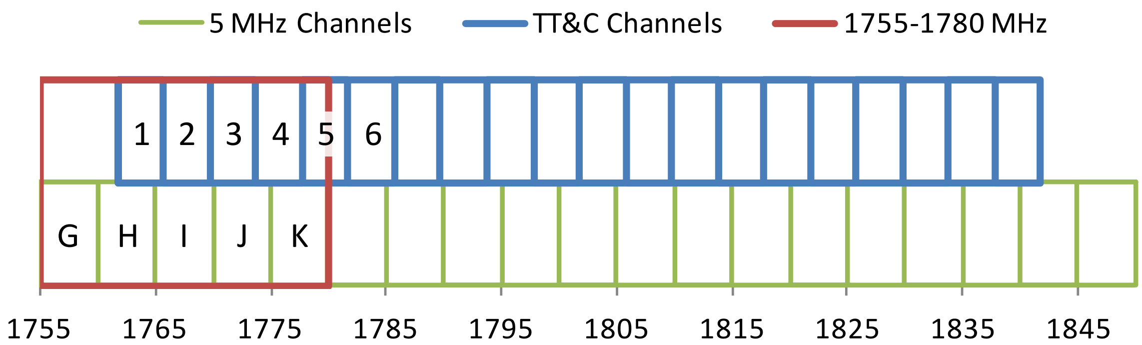


Figure 4.2.3-11: Channel overlap between SGLS channels and Commercial Channels.

Due to this channelization not all of the emissions from a SGLS channel may fall with-in the commercial channel. The amount will depend on the spectral mask in use by the SGLS station. If the SGLS station is using the typical emission mask as indicated in Figure 4.2.1-3 then no reduction will needed due to the narrow operating frequency of the emissions under the assumption that the SGLS terminal will tune to all frequencies with-in the selected channel indicated in the above figure. If the SGLS terminal is operating using the legacy emission mask as indicated in Figure 4.2.1-4 then only a portion of the would impact any selected AWS channel that would overlap the selected channel.

An indication of the amount of reduction in operating power can be found by integrating the legacy emissions over the receiver bandwidth that overlaps and is representative by the Frequency Dependent Rejection (FDR) term in Section 4.2.3.2.2.1, the results are indicated in the below table. As an example if a SGLS station is using channel 2 then all power is with-in AWS channel I and no other AWS channels are co-channel. If a SGLS station is using channel 3, then AWS channel I is co-channel and would see a reduced power of 8.1 dB relative to full power operations, also AWS channel J is co-channel and would see power at a 0.9 dB reduced level relative to full power operations.

Table 4.2.3-13: Reduction of on-channel power for legacy emissions masks.

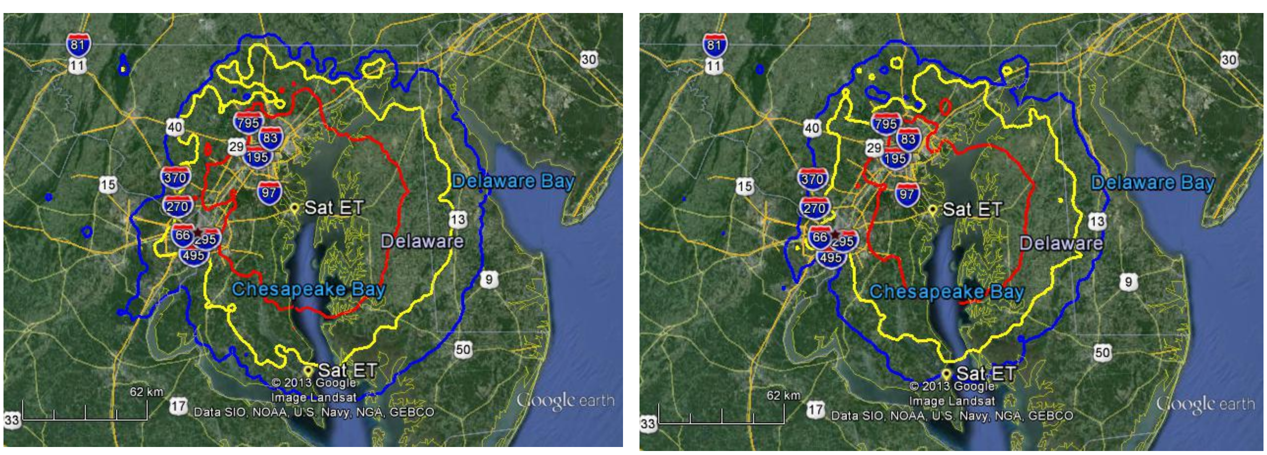
AWS Channel	SGLS Co-Channels	Overlap (%)	FDR (dB)
G			
H	1	81.90%	1.9
I	1, 2, 3	18.1%, 100%, 6.8%	4.7, 0.0, 8.1
J	3, 4	93.2%, 31.7%	0.9, 4.7
K	4, 5	68.3%, 56.6%	1.9, 2.0

Shown in Table 4.2.3-14 is a summary of the figures in this section to the specific site locations listed. All co-channel computations are performed under the assumption that the SGLS channel is fully with-in the receiver channel of an LTE Base station. To relate these results to a specific channel when the SGLS station is using the legacy emission mask, the factors discussed above in Table 4.2.3-13 need to be applied to the results.

The convention in the remainder of this Phase 1 analysis for the figures is that the blue line is for the Baseline case, the yellow line is for the Opt 1 case and the red line is for the Opt 2 case listed in Table 4.2.3-10. The data is computed by use of the ITM propagation model in point-to-point mode when distributing BS within a distance of 200 km around the Satellite uplink terminal in a hexagonal grid with inter-site distance between BS of 7 km.

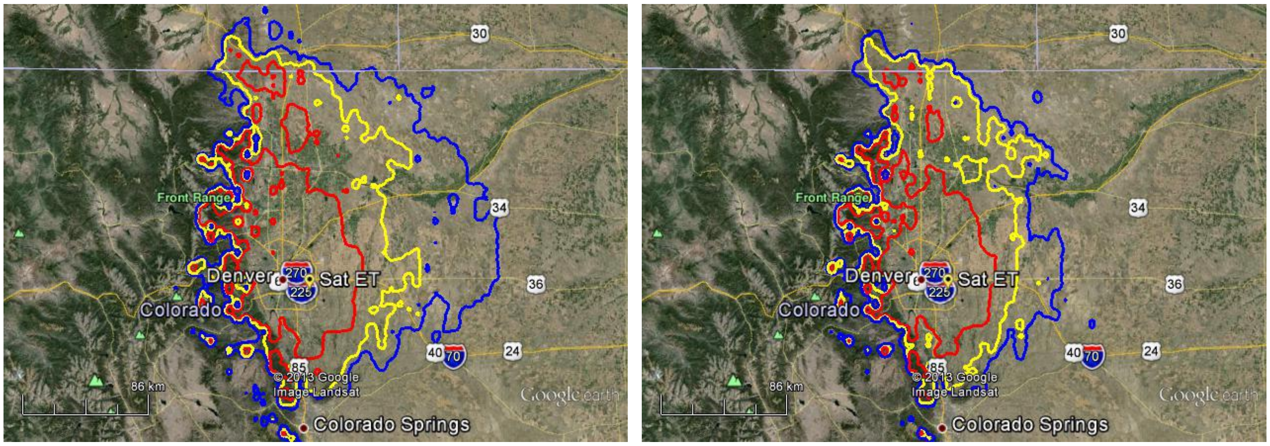
Table 4.2.3-14: Summary Table

SATOPS Sites	Figure	Note
AN, MD	Figure 4.2.3-12	
BAFB	Figure 4.2.3-13	
BP, MD	Figure 4.2.3-14	
CAPEG	Figure 4.2.3-15	
CP, CA	Figure 4.2.3-16	Not Currently Operational
CTS	Figure 4.2.3-17	
EVCF	Figure 4.2.3-18	
FB, AK	Figure 4.2.3-19	
FB, NC	Figure 4.2.3-20	
FB, VA	Figure 4.2.3-21	
FH, TX	Figure 4.2.3-22	
GNS	Figure 4.2.3-23	
GTS	Figure 4.2.3-24	
HB, CA	Figure 4.2.3-25	
HTS	Figure 4.2.3-26	
JB, WA	Figure 4.2.3-27	
KAFB	Figure 4.2.3-28	
KW, FL	Figure 4.2.3-29	
LP, CA	Figure 4.2.3-30	
MO, CA	Figure 4.2.3-31	
NHS	Figure 4.2.3-32	
PH, ME	Figure 4.2.3-33	
PR, MD	Figure 4.2.3-34	
SAC, CA	Figure 4.2.3-35	
VTS	Figure 4.2.3-36	



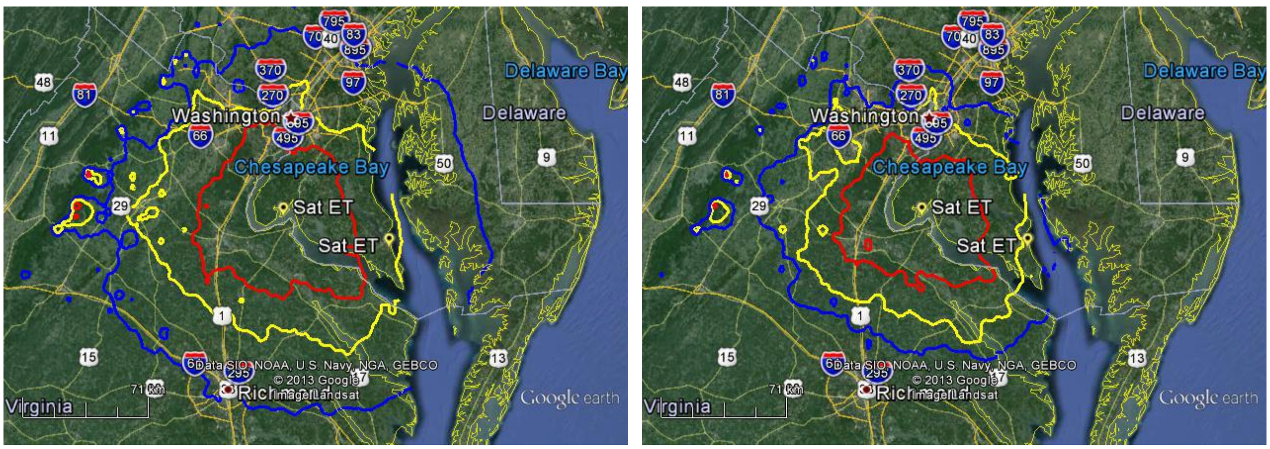
1 dB Desense　　3 dB Desense

Figure 4.2.3-12: AN, MD Site.



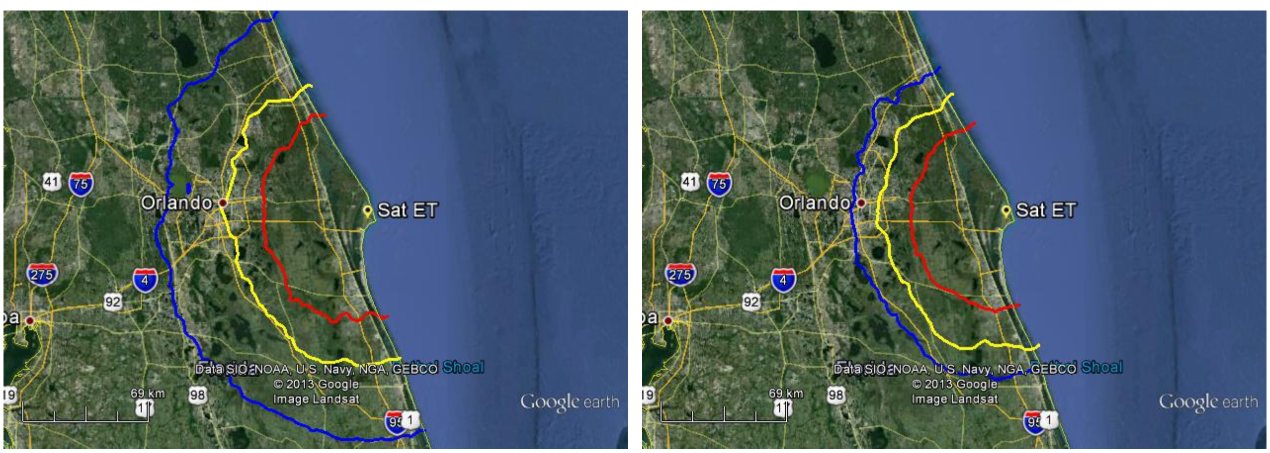
1 dB Desense 3 dB Desense

Figure 4.2.3-13: BAFB Site.



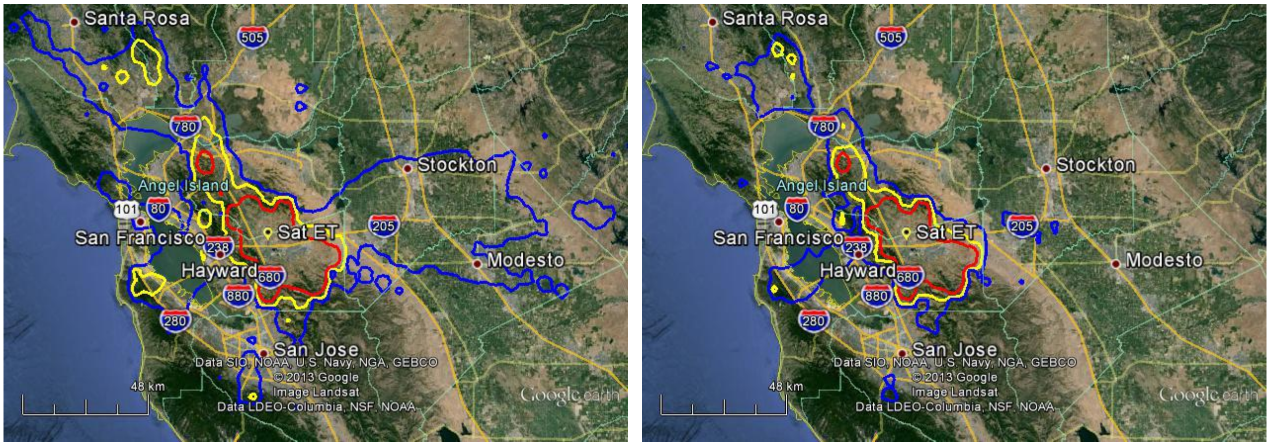
1 dB Desense 3 dB Desense

Figure 4.2.3-14: BP, MD Site.



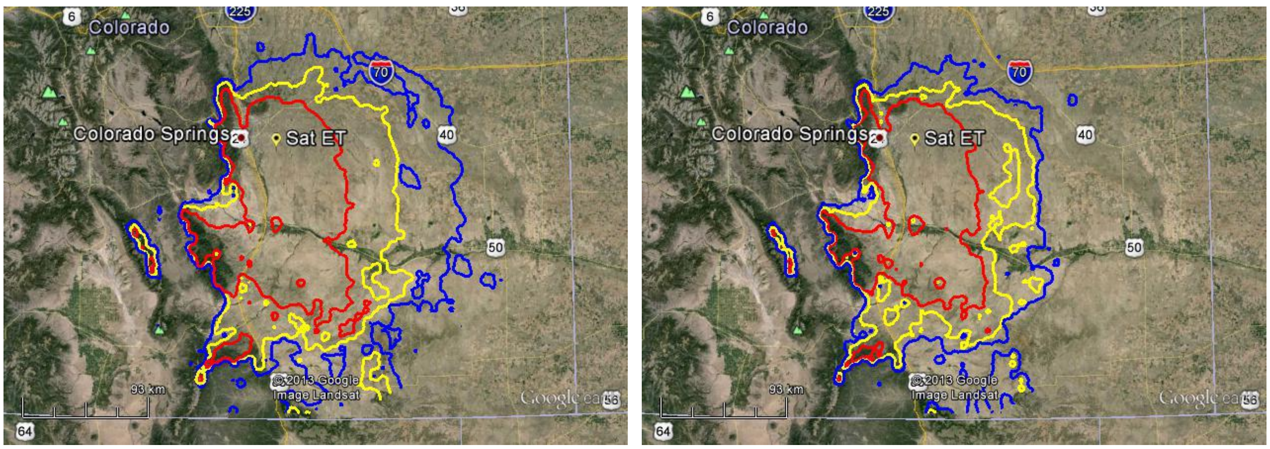
1 dB Desense 3 dB Desense

Figure 4.2.3-15: CAPEG Site.



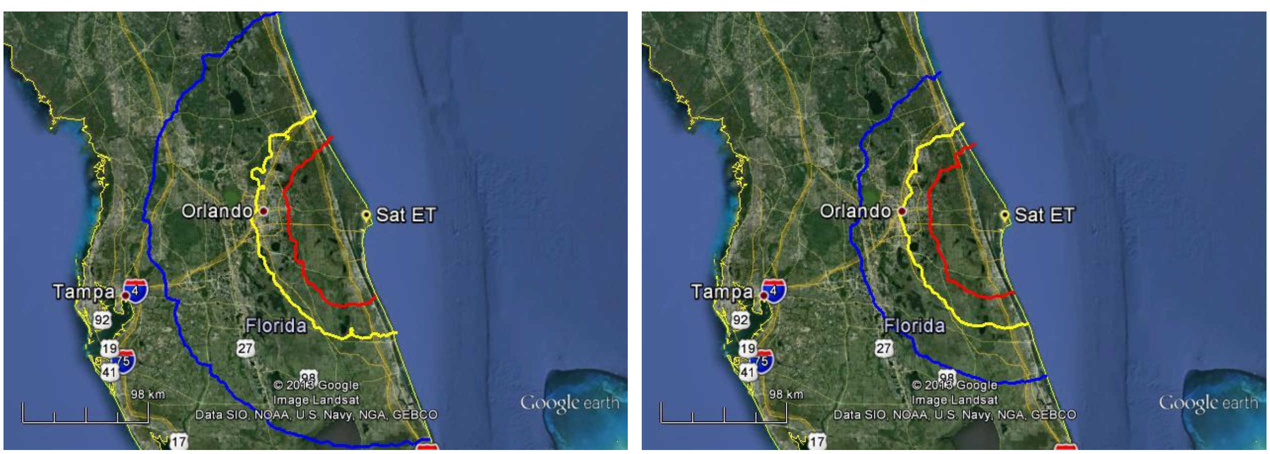
1 dB Desense   3 dB Desense

Figure 4.2.3-16: CP, CA Site.



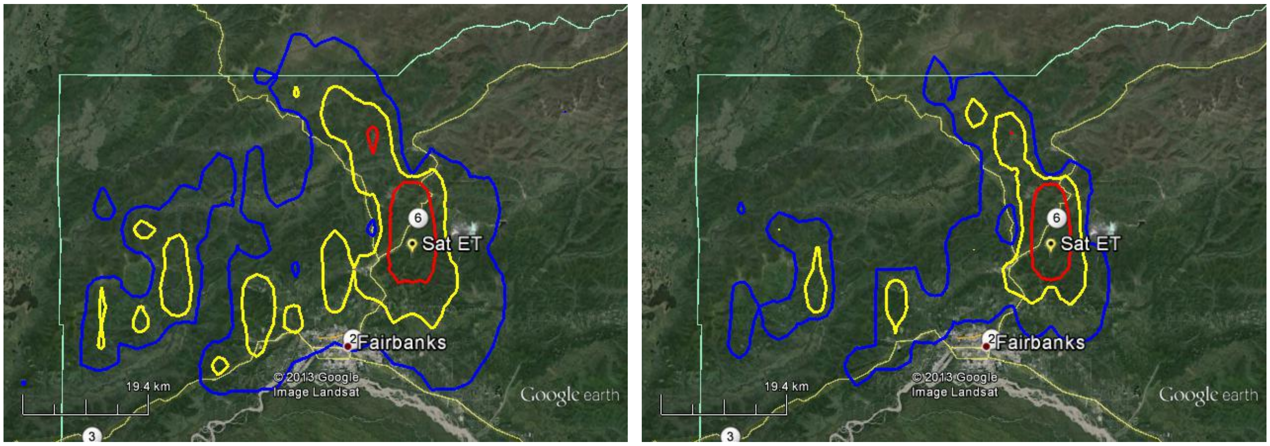
1 dB Desense   3 dB Desense

Figure 4.2.3-17: CTS Site.



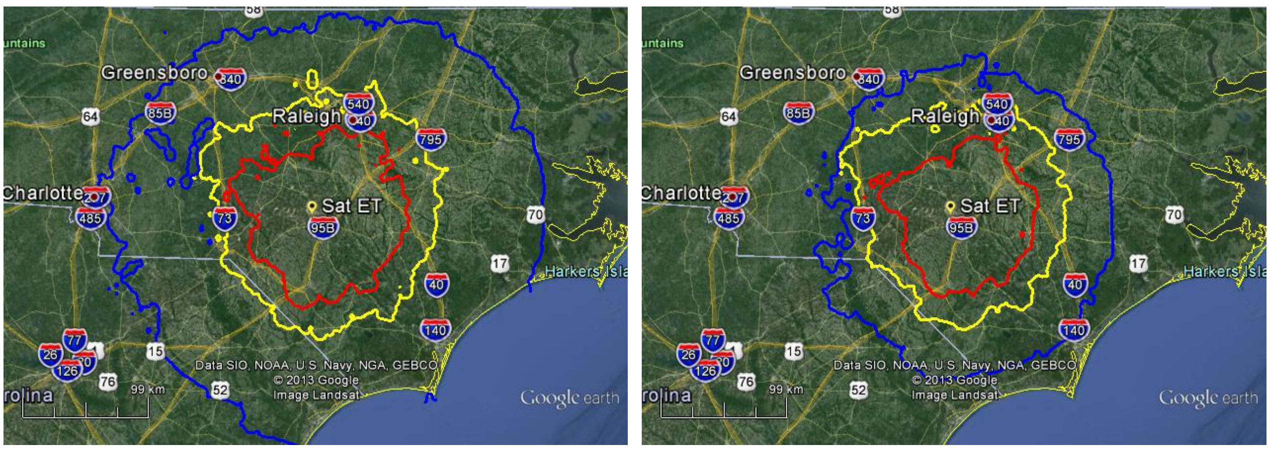
1 dB Desense   3 dB Desense

Figure 4.2.3-18: EVCF Site.



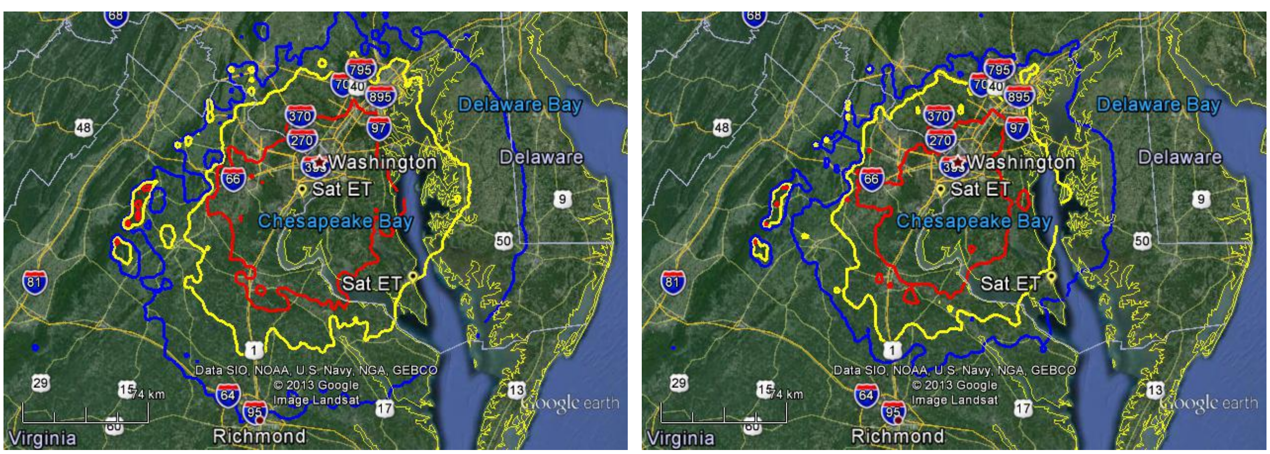
1 dB Desense 3 dB Desense

Figure 4.2.3-19: FB, AK Site.



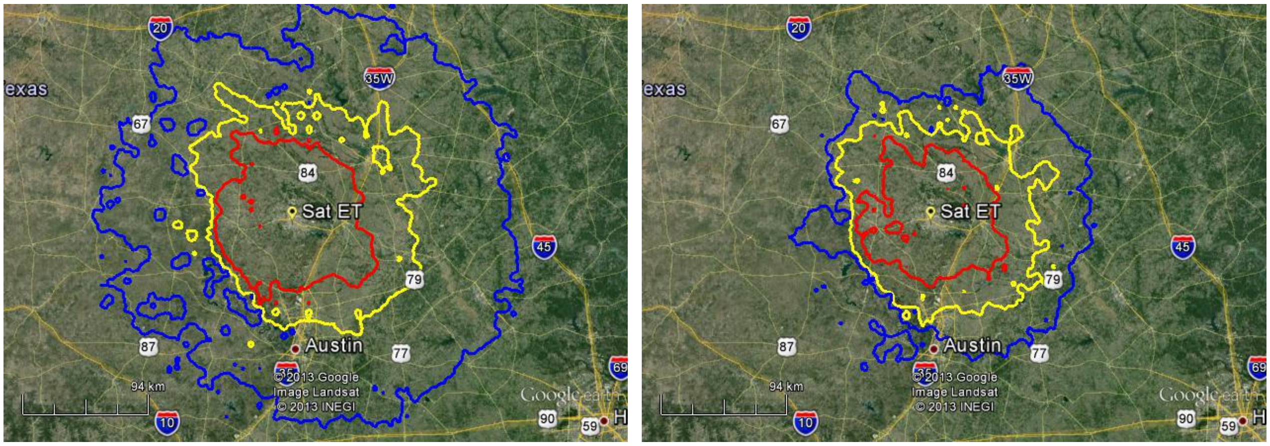
1 dB Desense 3 dB Desense

Figure 4.2.3-20: FB, NC Site.



1 dB Desense 3 dB Desense

Figure 4.2.3-21: FB, VA Site.

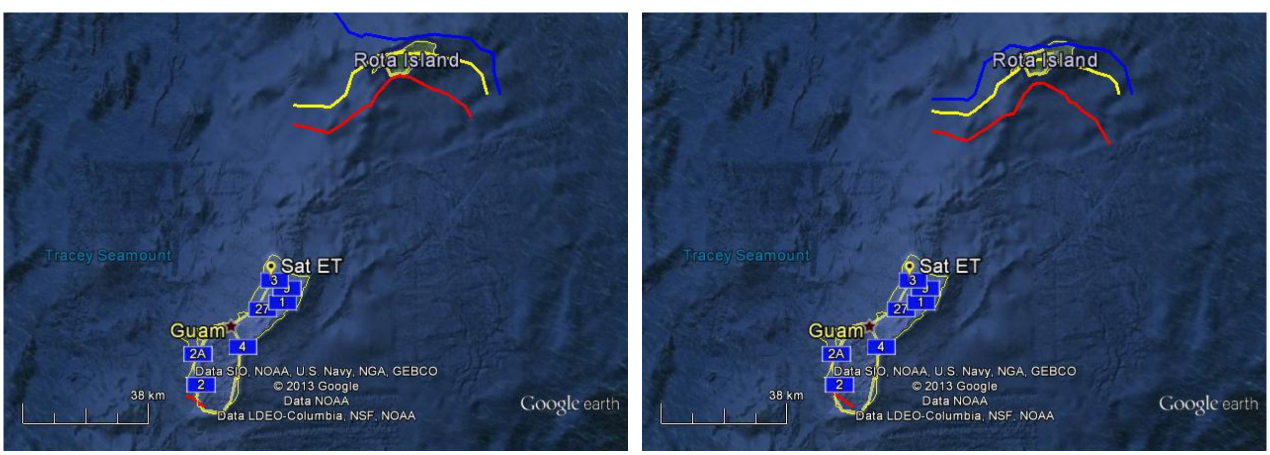


1 dB Desense 3 dB Desense

Figure 4.2.3-22: FH, TX Site.

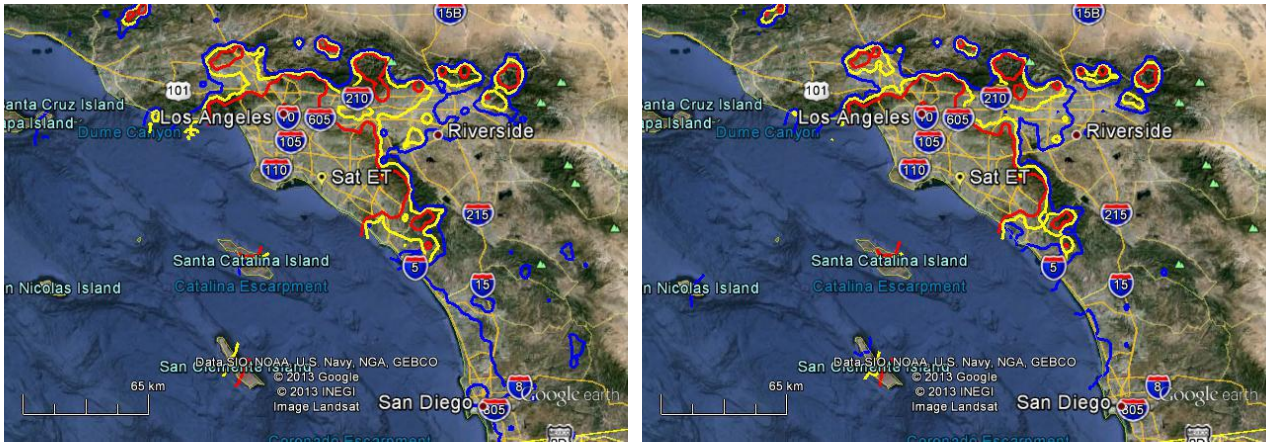
1 dB Desense 3 dB Desense

Figure 4.2.3-23: GNS Site.



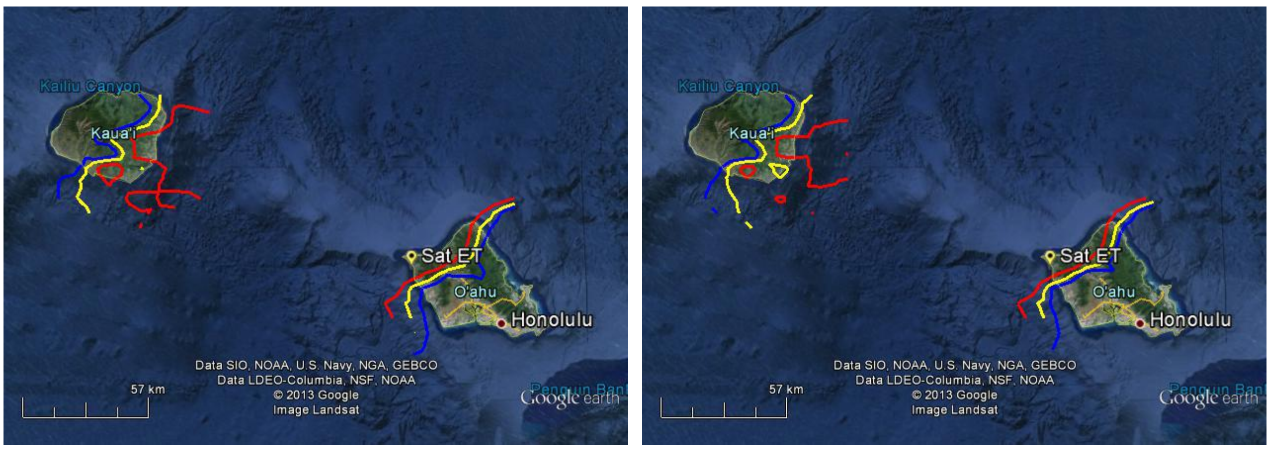
1 dB Desense 3 dB Desense

Figure 4.2.3-24: GTS Site.



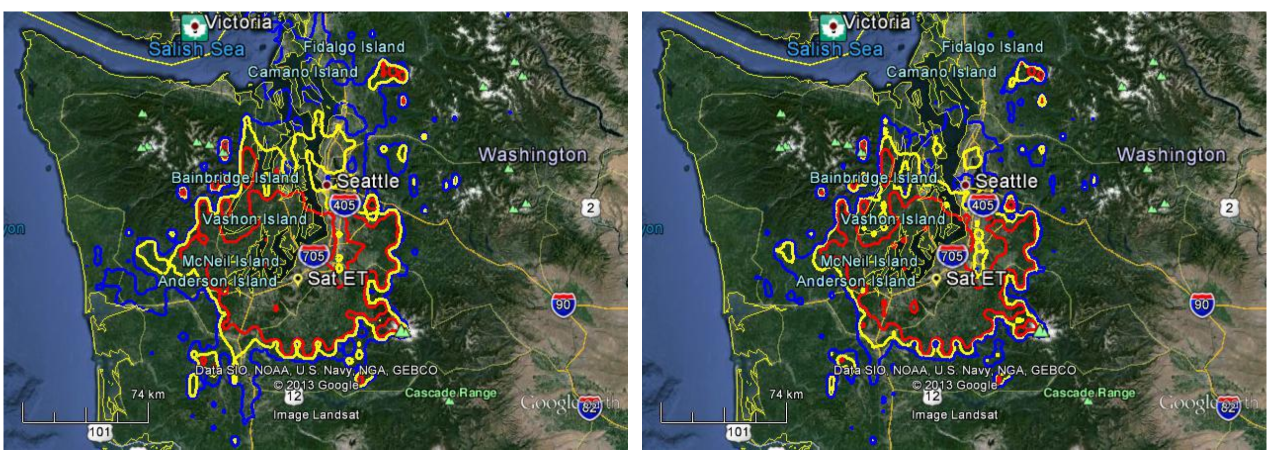
1 dB Desense 3 dB Desense

Figure 4.2.3-25: HB, CA Site.



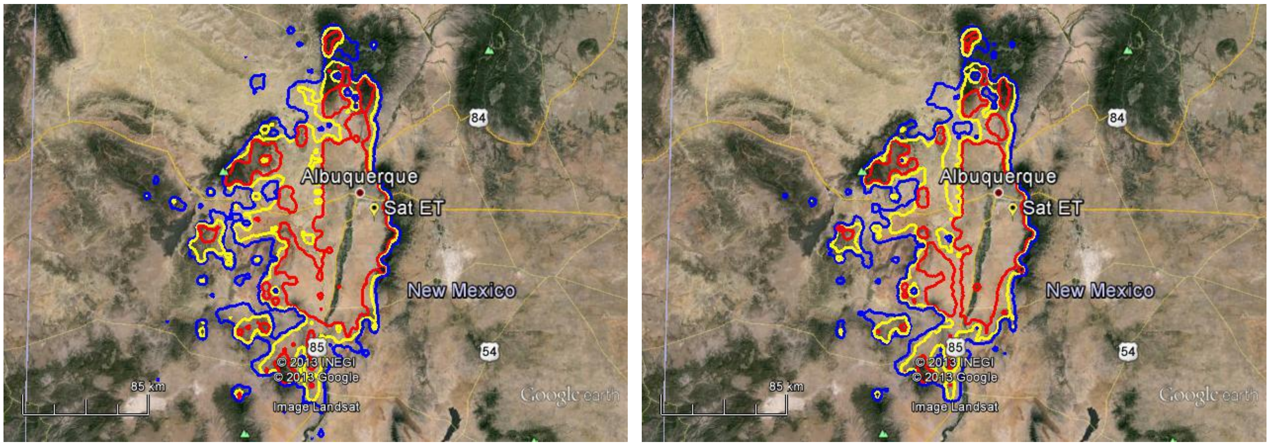
1 dB Desense 3 dB Desense

Figure 4.2.3-26: HTS Site.



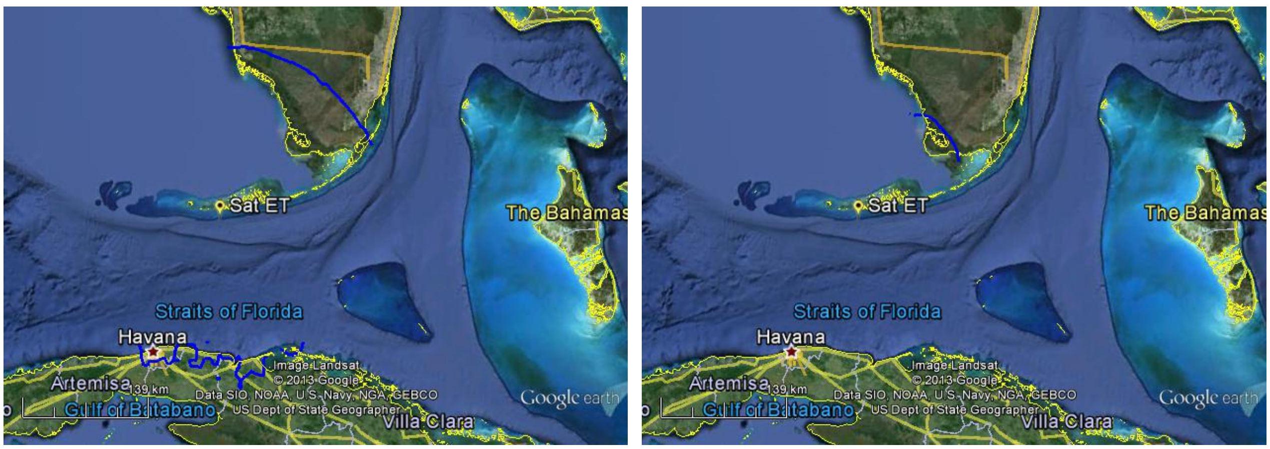
1 dB Desense 3 dB Desense

Figure 4.2.3-27: JB, WA Site.



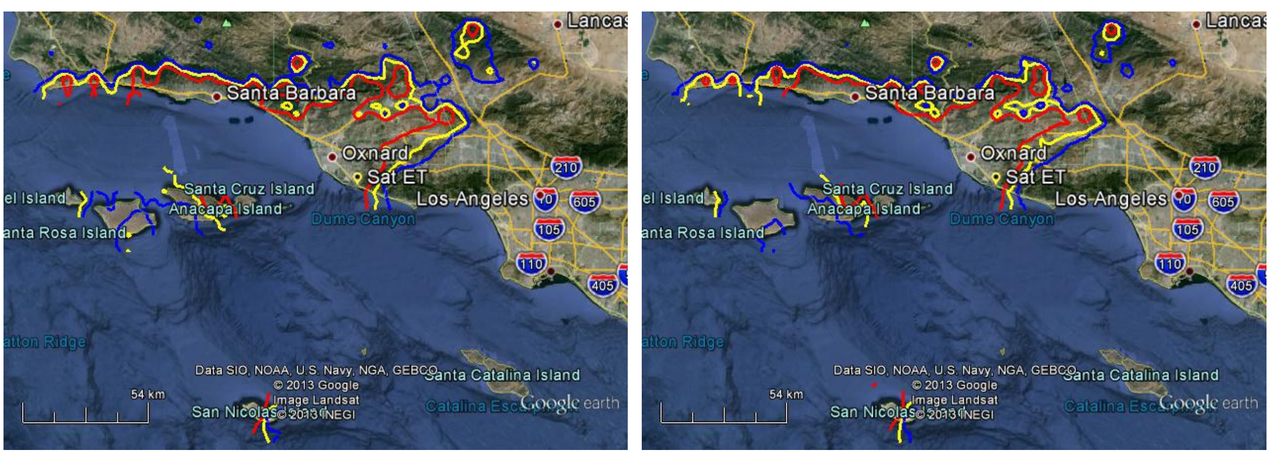
1 dB Desense 3 dB Desense

Figure 4.2.3-28: KAFB Site.



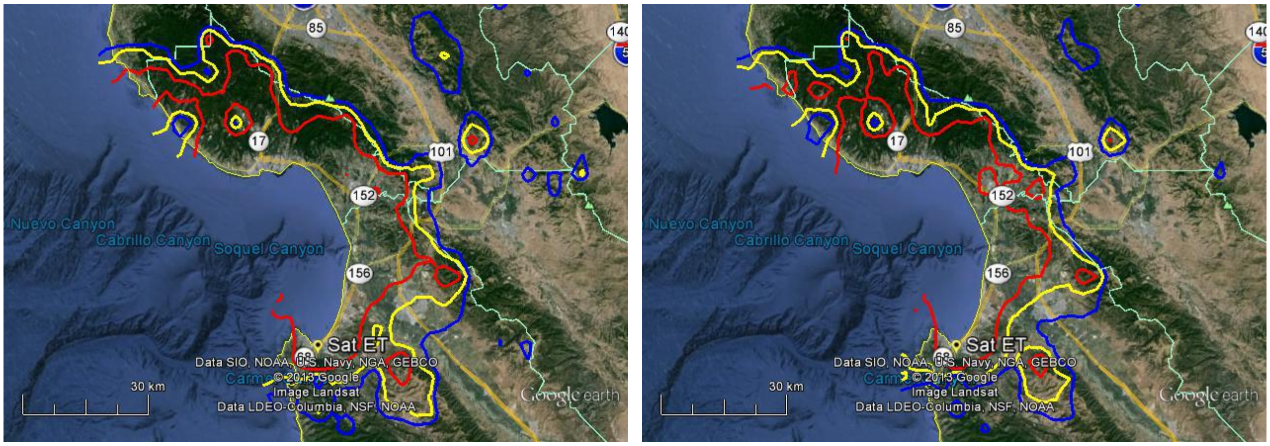
1 dB Desense 3 dB Desense

Figure 4.2.3-29: KW, FL Site.



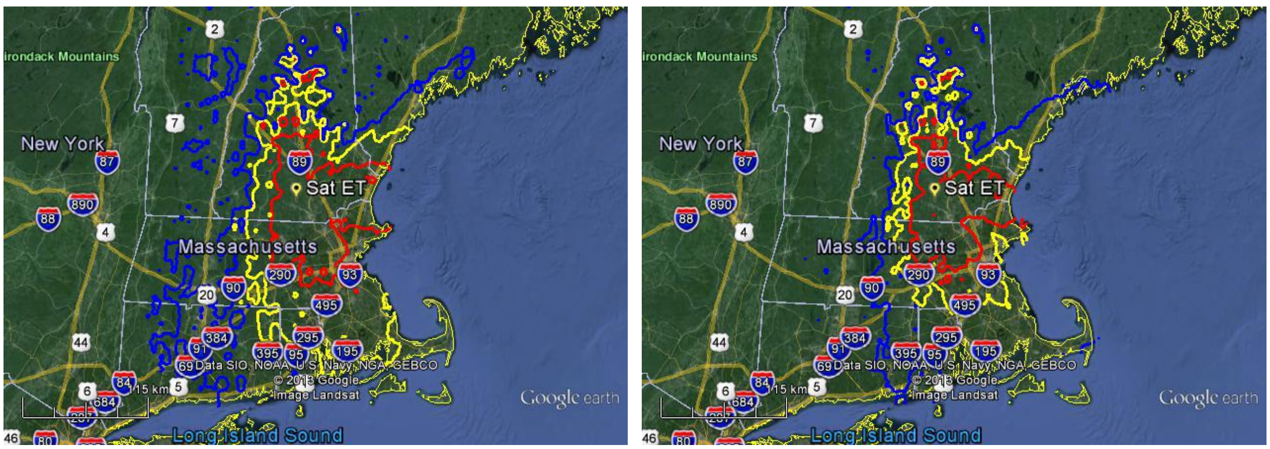
1 dB Desense 3 dB Desense

Figure 4.2.3-30: LP, CA Site.



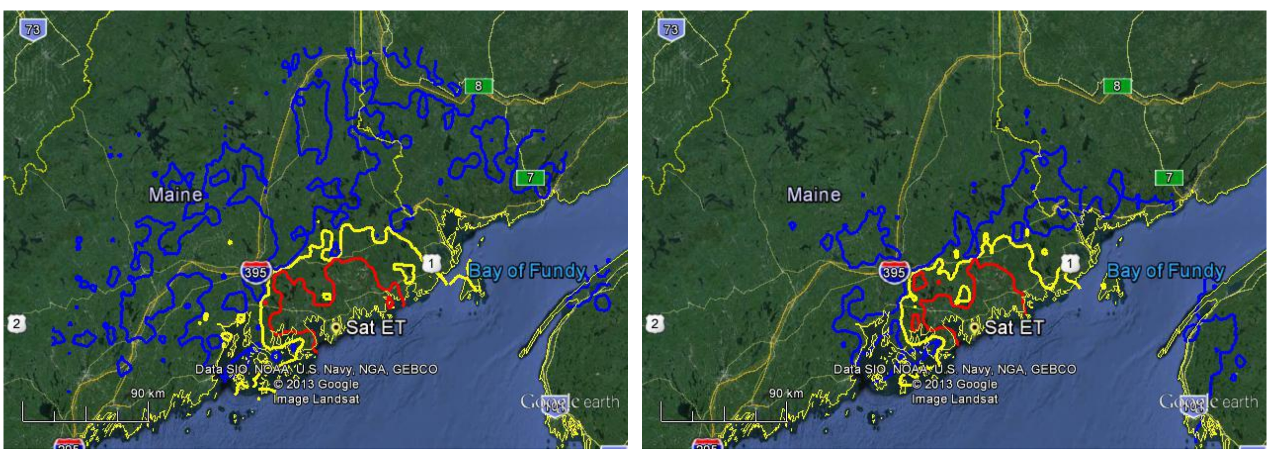
1 dB Desense 3 dB Desense

Figure 4.2.3-31: MO, CA Site.



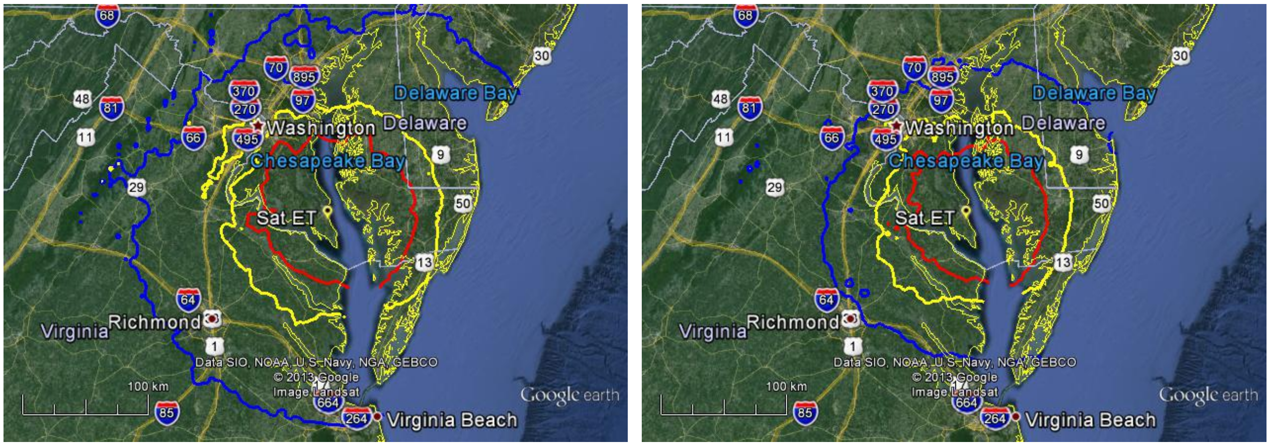
1 dB Desense 3 dB Desense

Figure 4.2.3-32: NHS Site.



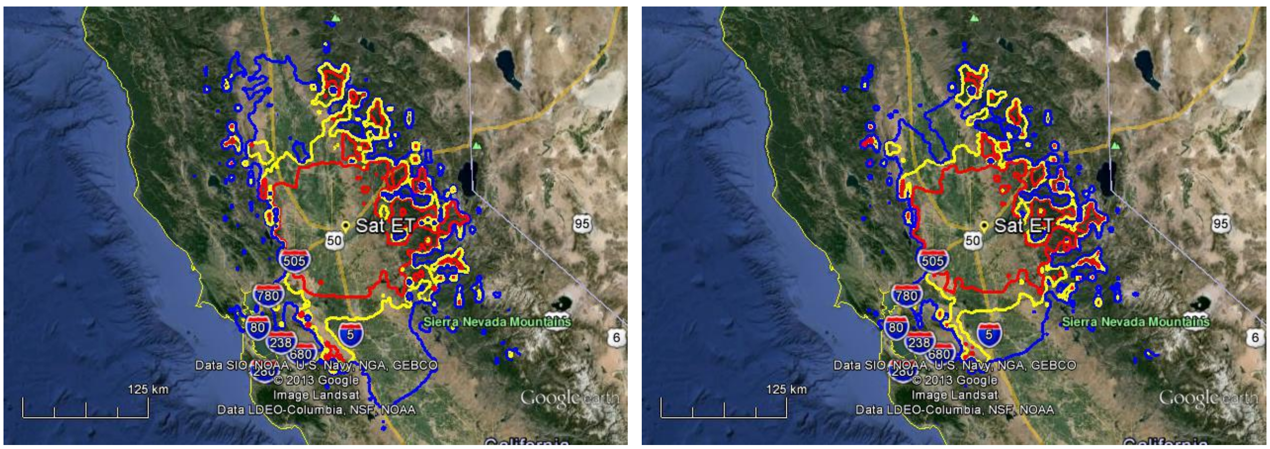
1 dB Desense 3 dB Desense

Figure 4.2.3-33: PH, ME Site.



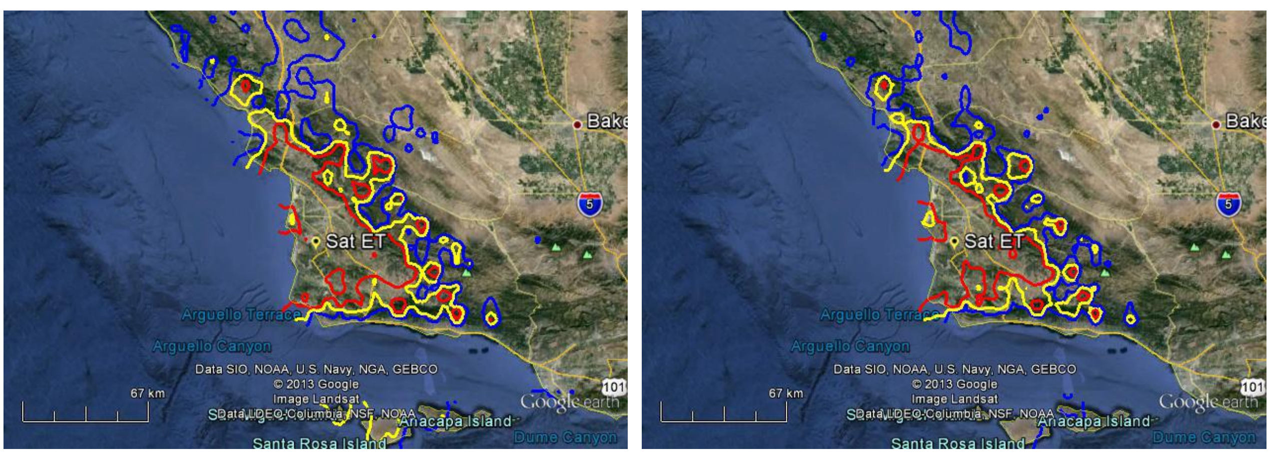
1 dB Desense 3 dB Desense

Figure 4.2.3-34: PR, MD Site.



1 dB Desense 3 dB Desense

Figure 4.2.3-35: SAC, CA Site.



1 dB Desense 3 dB Desense

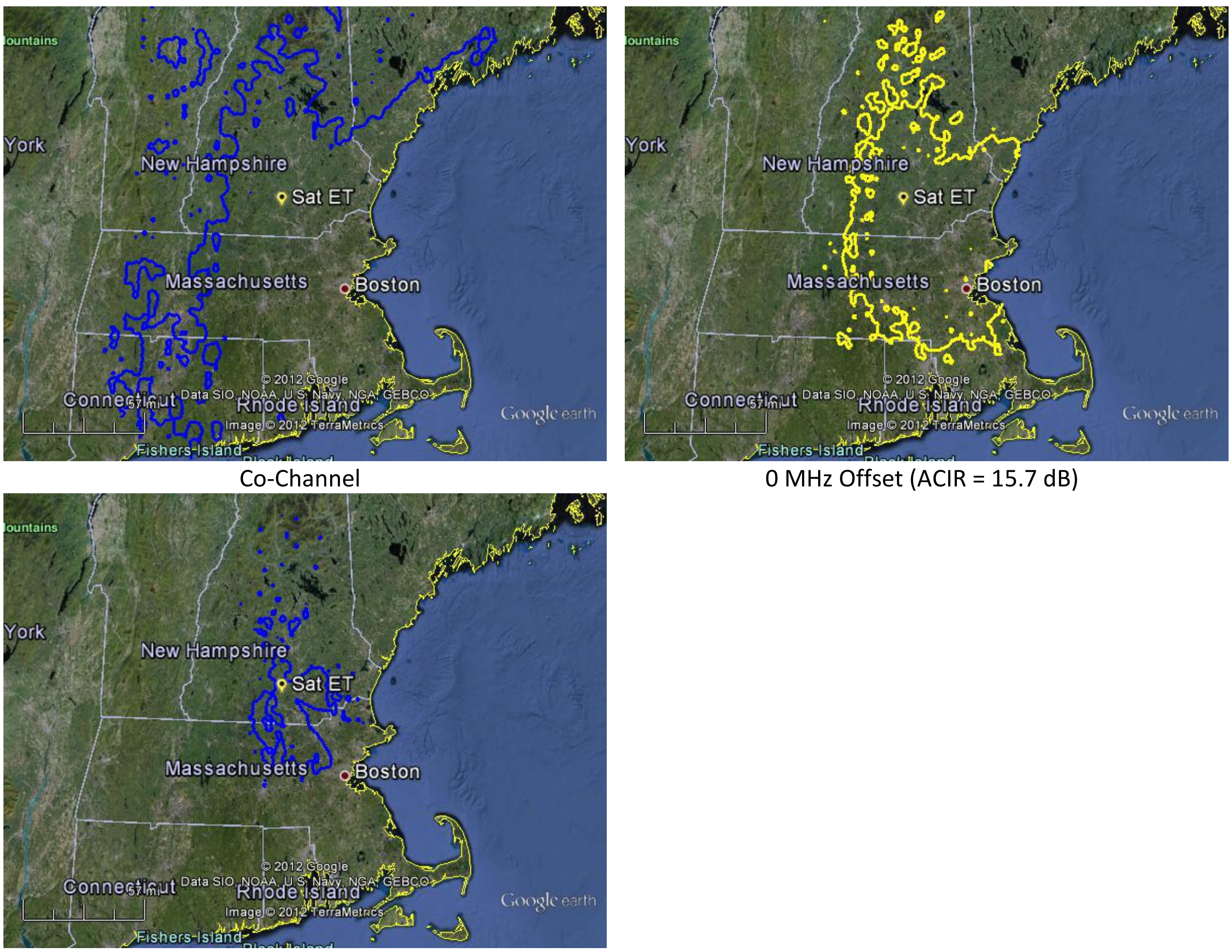
Figure 4.2.3-36: VTS Site.

4.2.3.2.3.1.2 Adjacent Channel Operations

When considering the adjacent channel operations the specific channelization of both the SGLS operation and the commercial base stations, along with the emission mask of the SGLS terminal, will determine the amount of interference present.

4.2.3.2.3.1.2.1 Future Mask

For the case of the future mask as found in Figure 4.2.1-3 the adjacent channel offset will be as small as 0 MHz depending on the exact frequency the SGLS terminal is tuned to for operation. For this analysis results will be shown for a 0 MHz offset and a 1 MHz offset. Based on the results found in Table 4.2.3-5 the ACIR is 15.7 dB and 49.5 dB, respectively.



Co-Channel

0 MHz Offset (ACIR = 15.7 dB)

1 MHz Offset (ACIR = 49.5 dB)

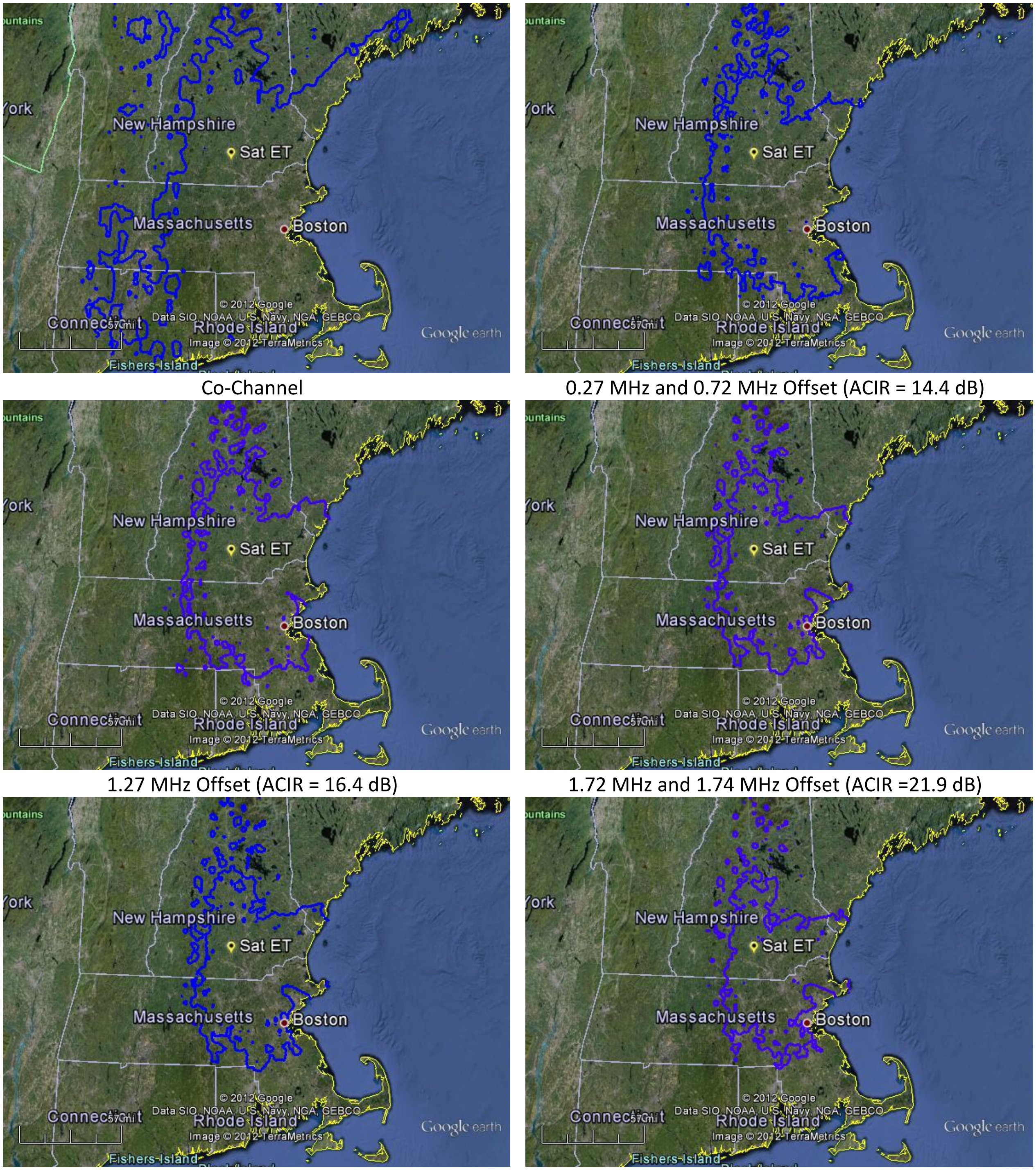
Figure 4.2.3-37: NHS Site adjacent channel offset 1 dB desense curves.

4.2.3.2.3.1.2.2 Legacy Mask

For the case of the Legacy mask as found in Figure 4.2.1-4 the adjacent channel offset will be between 0.27 and 3.73 MHz based on the 5 MHz base station channelization. The results in this section are found in Figure 4.2.3-38.

Table 4.2.3-15. ACIR for Legacy Mask.

AWS Channel	SGLS Adj-Channels	Minimum Offset (MHz)	ACIR (dB)
G	1	1.72	21.9
H	2	0.72	14.4
I	4	3.73	27.2
J	2, 5	0.27, 2.74	14.4, 22.2
K	3, 6	1.27, 1.74	16.4, 21.9



Co-Channel

0.27 MHz and 0.72 MHz Offset (ACIR = 14.4 dB)

1.27 MHz Offset (ACIR = 16.4 dB)

1.72 MHz and 1.74 MHz Offset (ACIR =21.9 dB)

2.74 MHz Offset (ACIR = 22.2 dB)

3.73 MHz Offset (ACIR = 27.2 dB)

Figure 4.2.3-38: NHS Site adjacent channel offset 1 dB desense curves.

4.2.3.2.3.2 Case B – Statistical Interference Levels

Case B is based on the assumption that the SATOPS antenna is always pointing at a selected satellite. When the SATOPS station is communicating with a GSO satellite there is no time variation of the pointing angle. When the SATOPS station is communicating with an NGSO satellite the pointing angle will change with time and the interference level at any BS receiver will also vary with time. For case B the same method of finding the interference level as described in Section 4.2.3.2.3.1.1 is used, but in this case a histogram of the interference level will be captured.

Analysis in this section will be based on one year of simulation time with a sample increments of one second.

Shown in Figure 4.2.3-40 is the simulation results based on the assumption that the satellite being tracked is that of USKW and the tracking station is located at the NHS location. This satellite uses SGLS channel 1 (see Section 4.2.1.1.1), and is a near polar orbiting satellite with an inclination angle of 98 degrees operates at an altitude of 630 km. The percentages listed in the figure is a conditional percentage of the interference level, the condition is that the SATOPS terminal is transmitting on the specific channel of interest. As an example of the below data, if the SATOPS terminal is communicating on channel 1 every time the USKW satellite passes, the maximum time that the satellite USKW is above the minimum elevation angle of 3 degrees would be 3.22% of the year. This would mean that given a conditional interference level at 75% of time, the total probability that the interference is at or above this level would be 0.805%.[27] Note that this may not be representative of actual SGLS channel use, actual use will take into account all the satellite systems to be contacted over all the SGLS channels potentially in use. The 0.805% of the time in this case would represent an upper bound of the time in operation if only the USKW satellite system is operational in channel 1.

An example of the interference at one particular simulated base station is shown in Figure 4.2.3-39. This result is for a base station located at 42.63N 72.22W, about 60 km from the Satellite uplink terminal. The percentages indicate the probability of the interference at or below the level indicated in the figure.

---

[27] This is computed by

$$P(I \geq Io) = 1 - P(I<Io) = 1-[P(I<Io|Ton)*P(Ton)+P(I<Io|Toff)*P(Toff)]$$

Where

$P(I \geq Io)$ = Probability that Interference is at or above Io

$P(I<Io)$ = Probability that interference is below Io

$P(I<Io|Ton)$ = Conditional probability that interference is below Io given that the SGLS transmitter is on

$P(I<Io|Toff)$ = Conditional probability that the interference is below Io given the SGLS transmitter is off

$P(Ton)$ = Probability that the SGLS transmitter is on

$P(Toff)$ = Probability that the SGLS transmitter is off

For the example given here:

$P(I<Io|Ton) = 75\%$

$P(I<Io|Toff) = 100\%$

$P(Ton) = 3.22\%$, assumes the SGLS transmitter is always on when the satellite is above the minimum elevation angle

$P(Toff) = 96.78\%$

$P(I \geq Io) = 1-[0.0322 * 0.75 + 1.00*0.9678]= 0.805\%$.

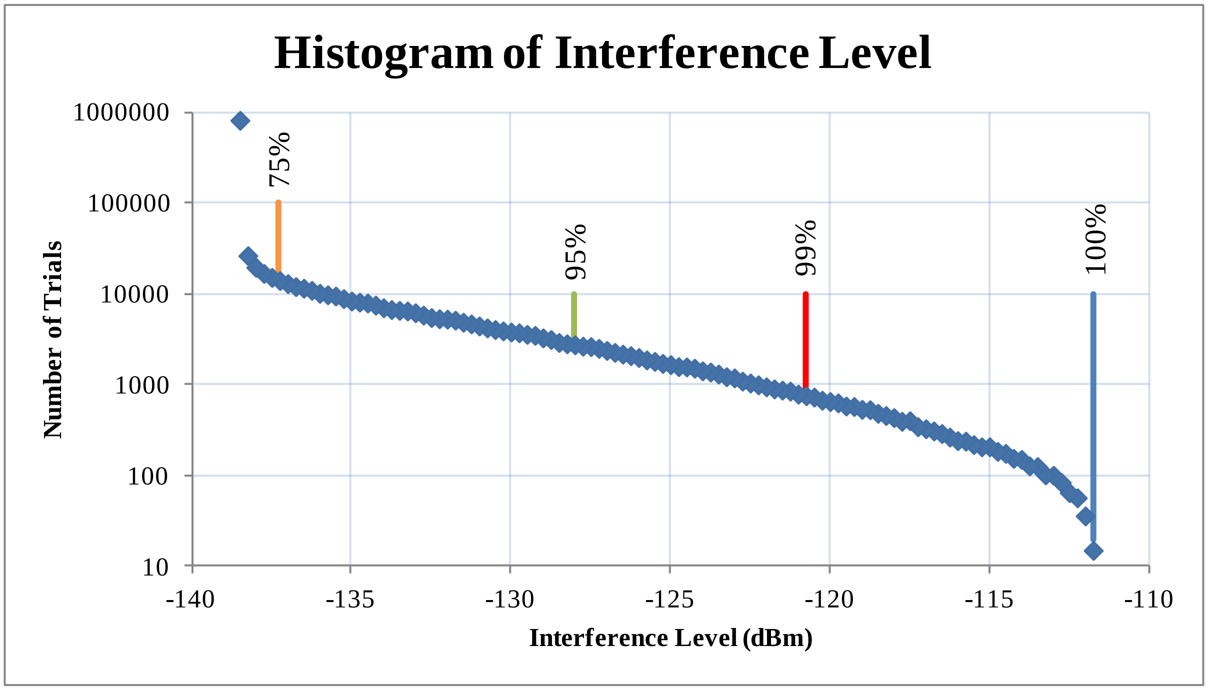
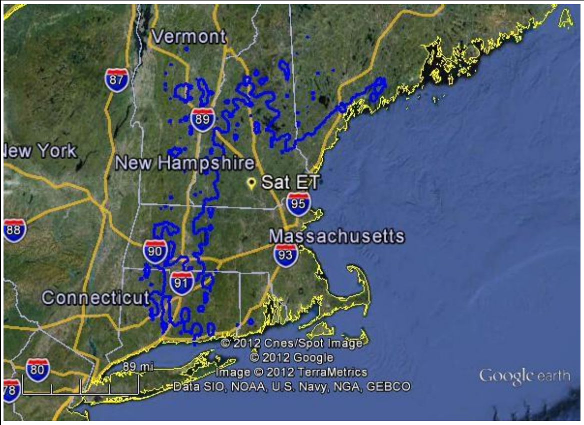


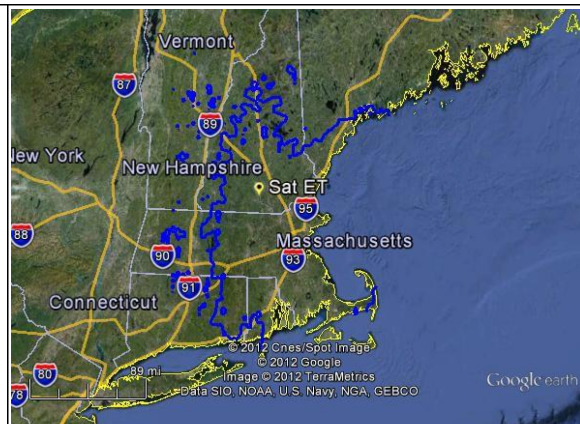
Figure 4.2.3-39. Histogram of interference level from satellite simulation.

Shown in Figure 4.2.3-41 is the simulation results based on the assumption that the satellite being tracked is that of USPOJOAQUE which uses SGLS channel 1 (see Section 4.2.1.1.1), this satellite has inclination angle of 40 degrees at operates at an altitude of 600 km.

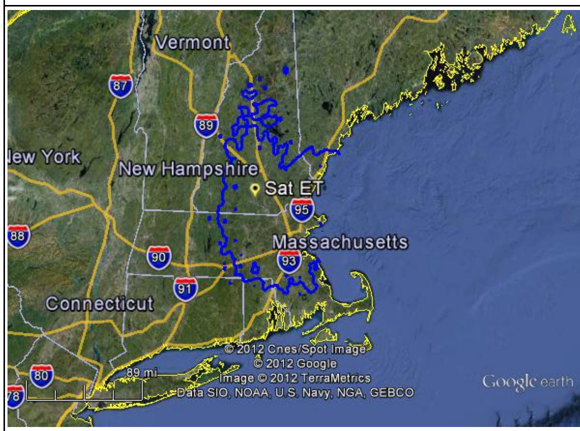
It should be noted that all these figures in this section are for the conditional probability that the interference is below the 1 dB desense level given the condition that the transmitter is on.



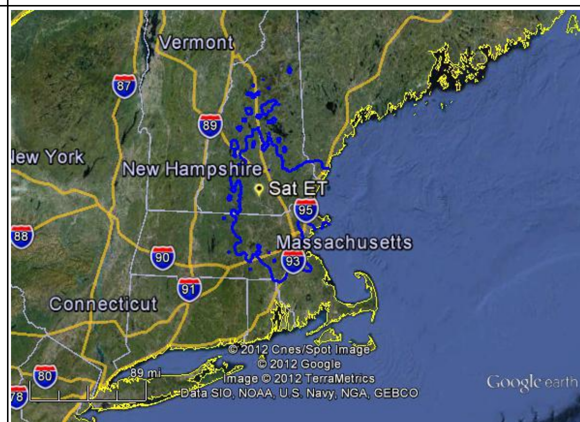
Interference of 1 dB desense assuming SATOPS terminal is pointing at 3 degrees elevation (no satellite tracking).



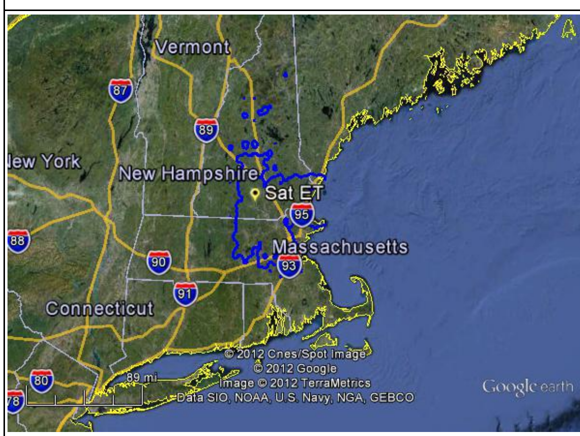
Interference at or below 1 dB desense for 100% of the time.



Interference at or below 1 dB desense for 99% of the time.



Interference at or below 1 dB desense for 95% of the time.



Interference at or below 1 dB desense for 75% of the time.

Figure 4.2.3-40. 1 dB Desense for NHS baseline scenario at various percentages of time, Satellite Inclination of 98 degrees.

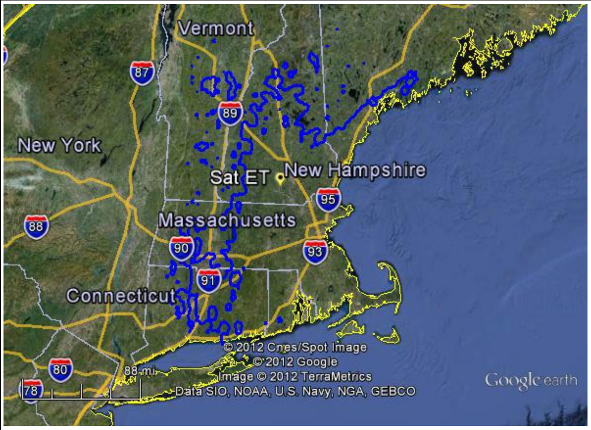
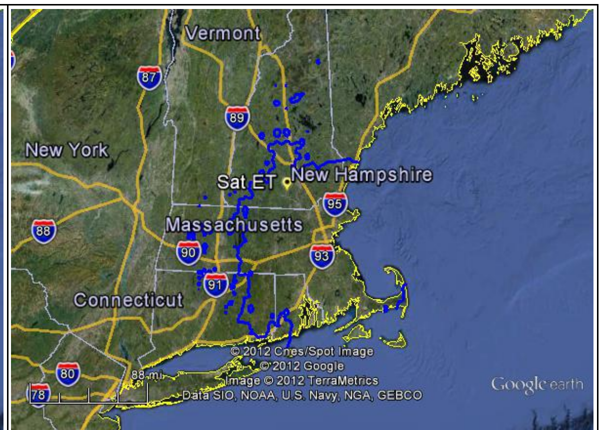
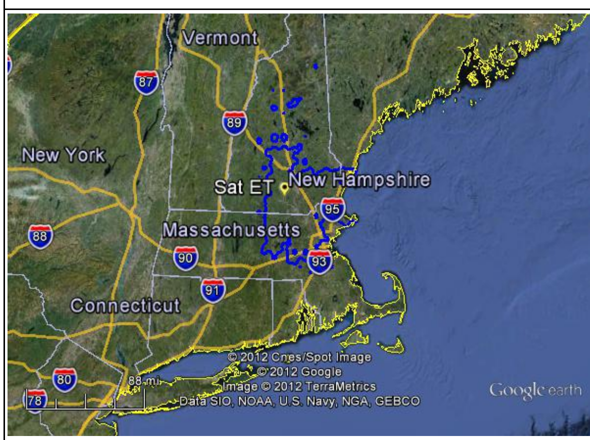
	
Interference of 1 dB desense assuming SATOPS terminal is pointing at 3 degrees elevation (no satellite tracking).	Interference at or below 1 dB desense for 100% of the time.
	
Interference at or below 1 dB desense for 99% of the time.	Interference at or below 1 dB desense for 95% of the time.
	
Interference at or below 1 dB desense for 75% of the time.	

Figure 4.2.3-41. 1 dB Desense for NHS baseline scenario at various percentages of time, Satellite Inclination of 40 degrees.

4.2.3.2.3.2.1 Co-Channel Operations

To perform analysis of co-channel operations it is assumed that the systems operating in the specific channels are based on ITU database information as indicated in Section 4.2.1.1.1. Figure 4.2.3-42 shows the graphic representation of SGLS channels in relation to 5 MHz channels. To reduce the amount of data collected and presented the 4 key tracking stations of New Hampshire (NHS), Vandenberg (VTS), Guam (GTS) and Hawaii (HTS) are presented. It should be noted that when relating the interference in a particular SGLS channel to the interference into a AWS channel, the discussion and factors in Section 4.2.3.2.3.1.1 should be considered.

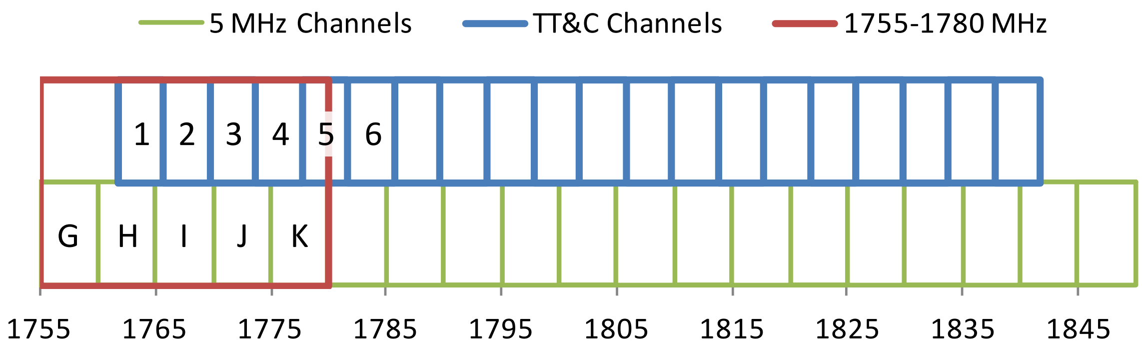


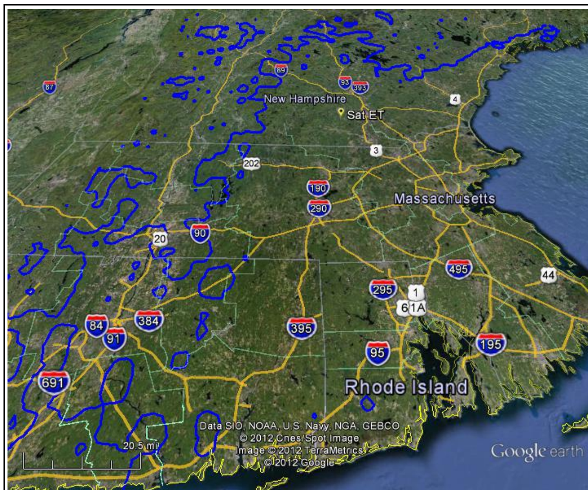
Figure 4.2.3-42. SGLS Channels

4.2.3.2.3.2.1.1 SGLS Channel 1

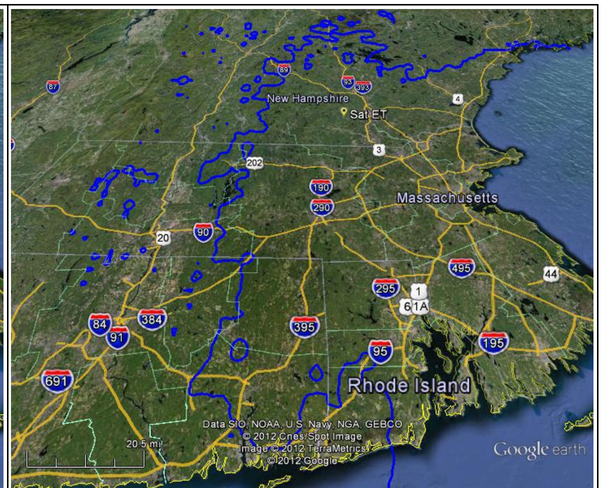
Table 4.2.3-16. ITU NGSO System data for Channel 1.

ITU Designation	Number of Satellites	Inclination (deg)	Apogee (km)	Perigee (km)	C/N (dB)	Noise Temp (K)	Max Gain (dBi)	Emission Designation
USKW	1	98	630	630	15	288	6	4M00G9D
USPOJOAQUE	1	40	600	600	15	290	2	2M00G1D
USYV	1	99	900	900	15	630	3	4M00G9D
L-92	12	55	1300	650	15	5000	0	4M00G7W

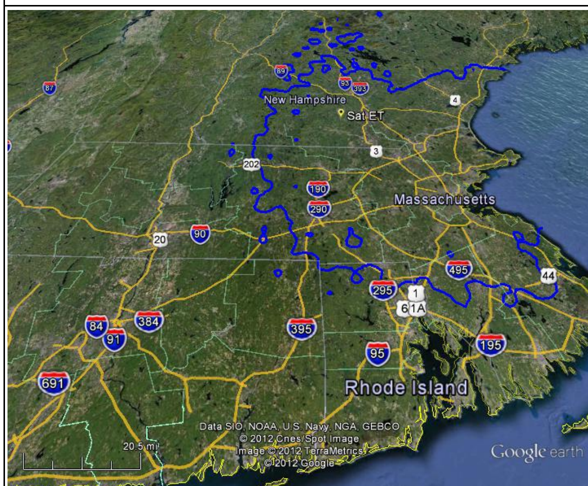
No GSO systems are listed in the ITU database for channel 1.



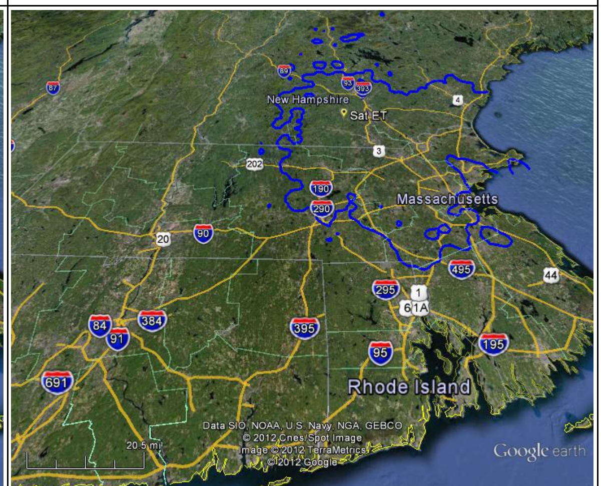
Interference of 1 dB desense assuming SATOPS terminal is pointing at 3 degrees elevation (no satellite tracking).



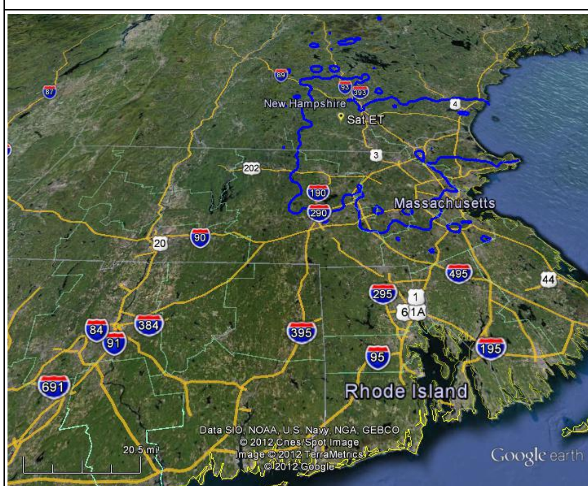
Interference at or below 1 dB desense for 100% of the time.



Interference at or below 1 dB desense for 99% of the time.



Interference at or below 1 dB desense for 95% of the time.



Interference at or below 1 dB desense for 75% of the time.

Figure 4.2.3-43. 1 dB Desense for NHS, baseline scenario at various percentages of time, Channel 1.

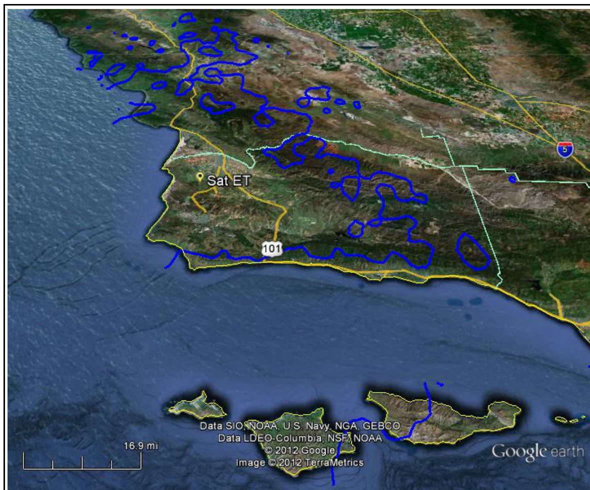
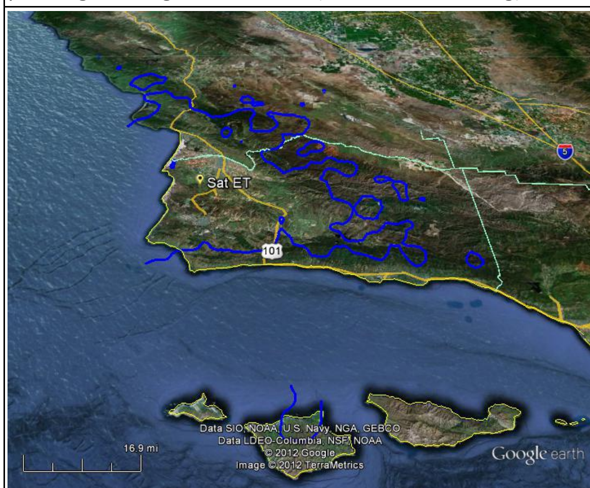
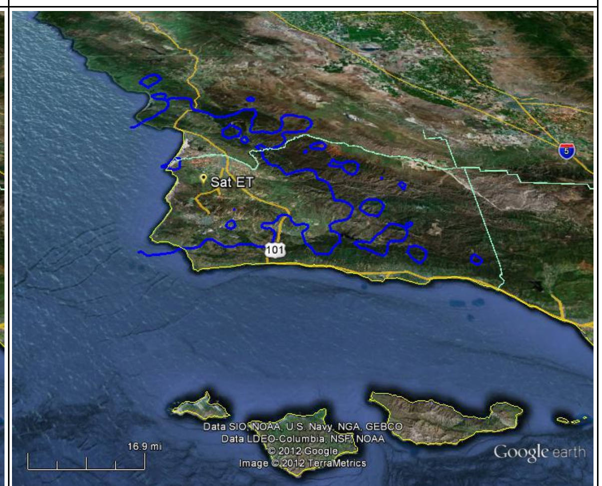
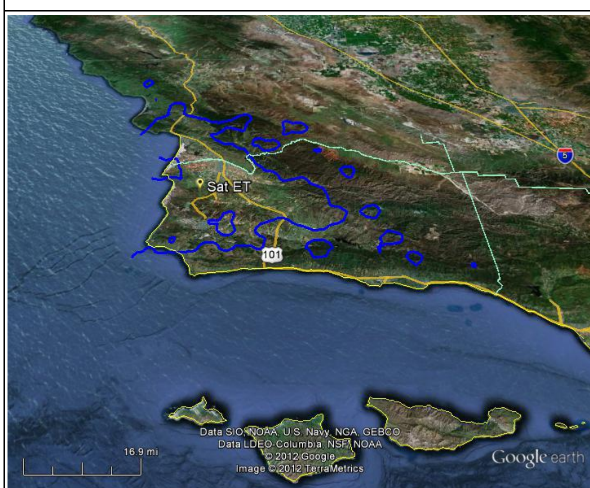
 	
Interference of 1 dB desense assuming SATOPS terminal is pointing at 3 degrees elevation (no satellite tracking).	Interference at or below 1 dB desense for 100% of the time.
 	
Interference at or below 1 dB desense for 99% of the time.	Interference at or below 1 dB desense for 95% of the time.
 	
Interference at or below 1 dB desense for 75% of the time.	

Figure 4.2.3-44. 1 dB Desense for VTS, baseline scenario at various percentages of time, Channel 1.

Interference of 1 dB desense assuming SATOPS terminal is pointing at 3 degrees elevation (no satellite tracking).

Interference at or below 1 dB desense for 100% of the time.

Interference at or below 1 dB desense for 99% of the time.

Interference at or below 1 dB desense for 95% of the time.

Interference at or below 1 dB desense for 75% of the time.

Figure 4.2.3-45. 1 dB Desense for HTS, baseline scenario at various percentages of time, Channel 1.

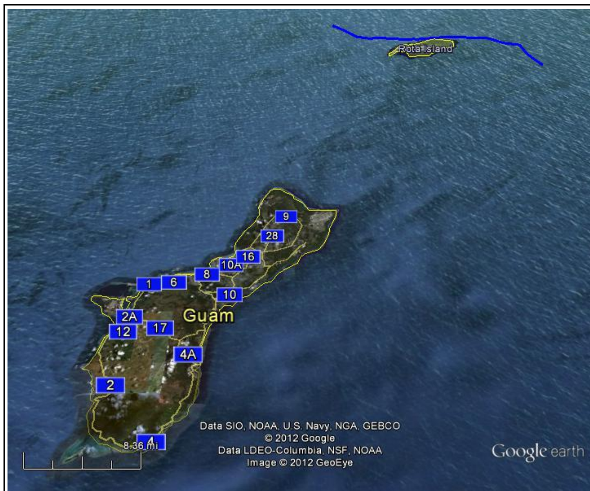
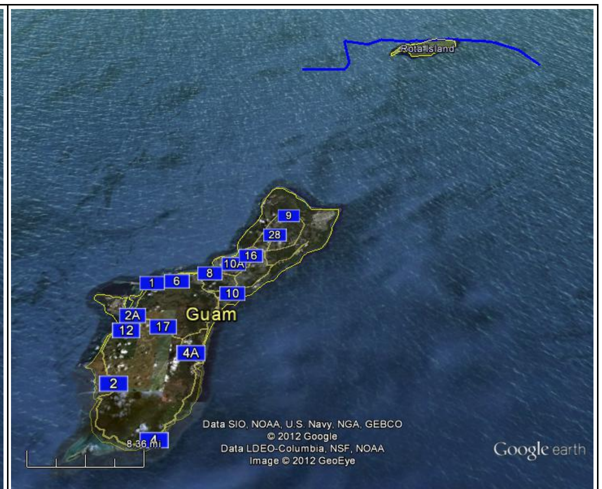
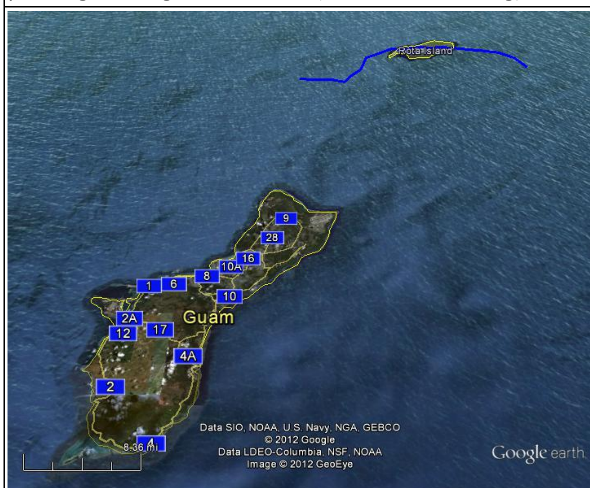
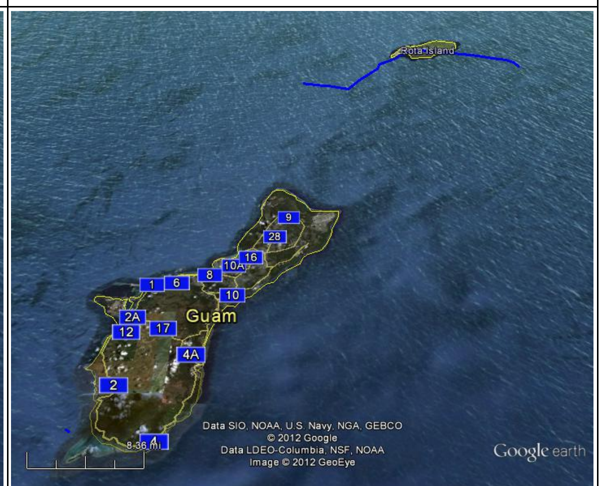
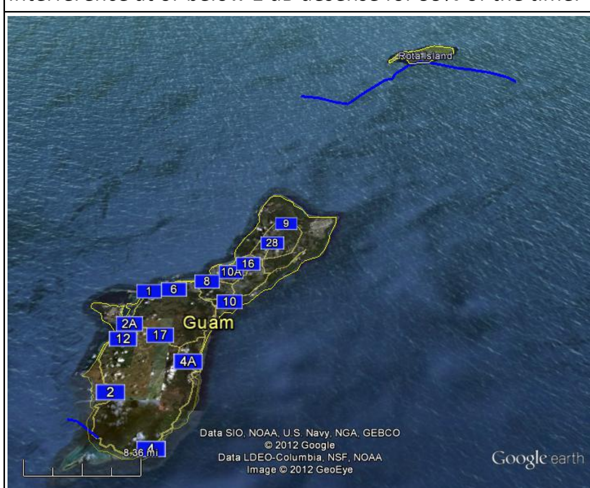
	
Interference of 1 dB desense assuming SATOPS terminal is pointing at 3 degrees elevation (no satellite tracking).	Interference at or below 1 dB desense for 100% of the time.
	
Interference at or below 1 dB desense for 99% of the time.	Interference at or below 1 dB desense for 95% of the time.
	
Interference at or below 1 dB desense for 75% of the time.	

Figure 4.2.3-46. 1 dB Desense for GTS, baseline scenario at various percentages of time, Channel 1.